Geologic History of Fluid Flow through the Arbuckle Group

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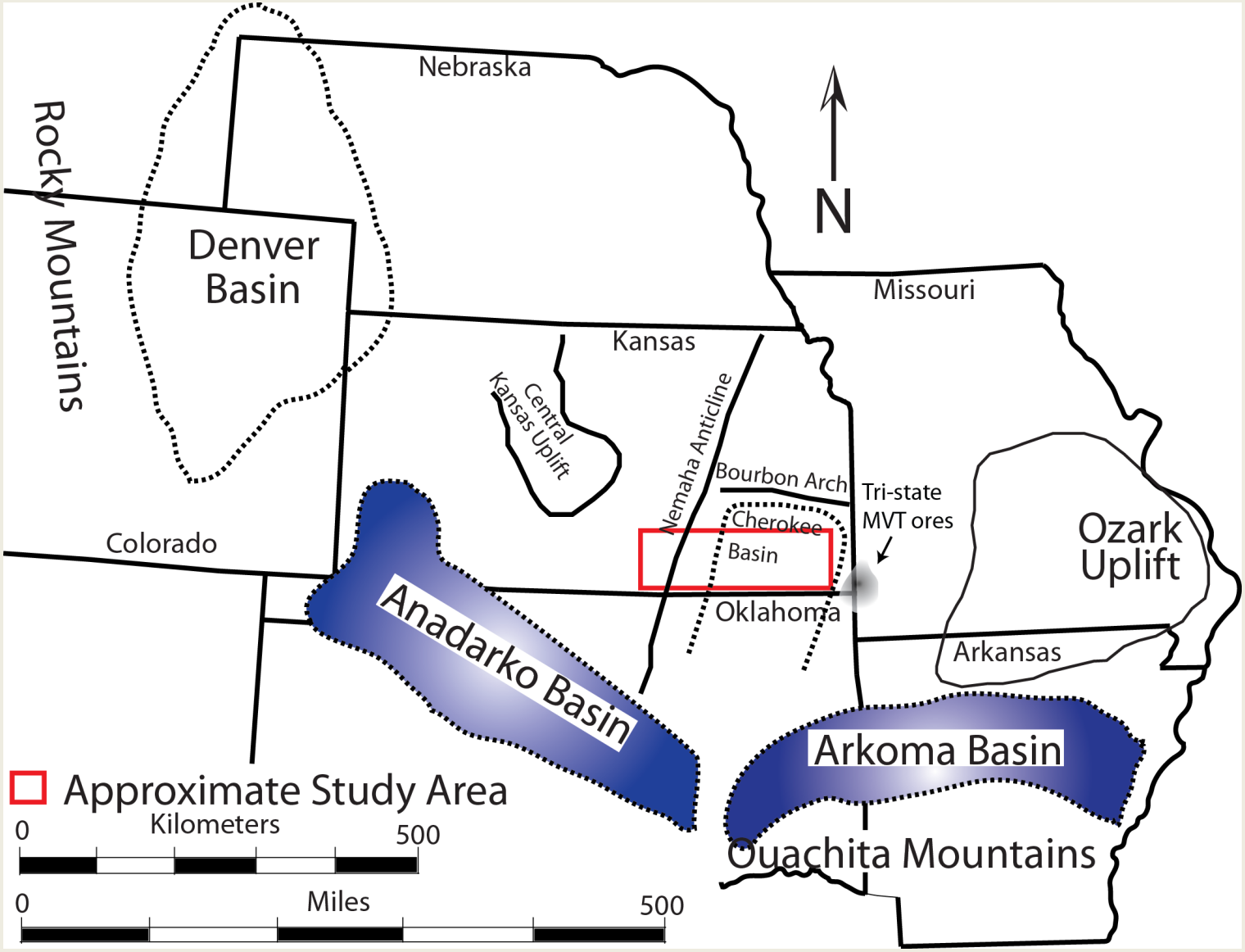
KICC

Kansas Interdisciplinary Carbonates Consortium

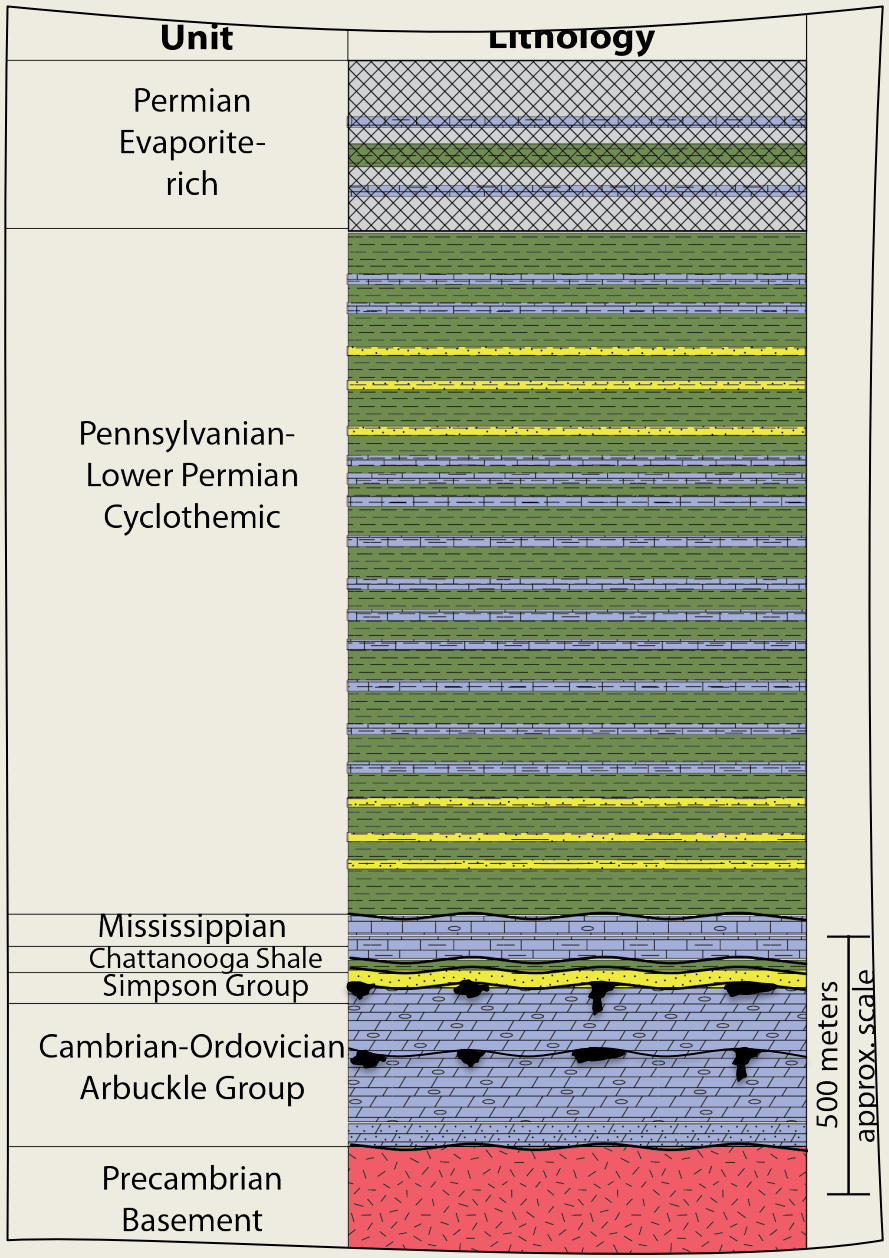
Purpose

- Diagenetic study of the Arbuckle Group
- Petrographic, fluid inclusion, and geochemical characteristics to characterize evolution of ancient fluid-flow systems
- Repeatedly not a closed system; given close to half a billion years of geologic history, there has been a complex and fascinating history of fluid flow driven by sea level change, climate, and tectonics

Study Area

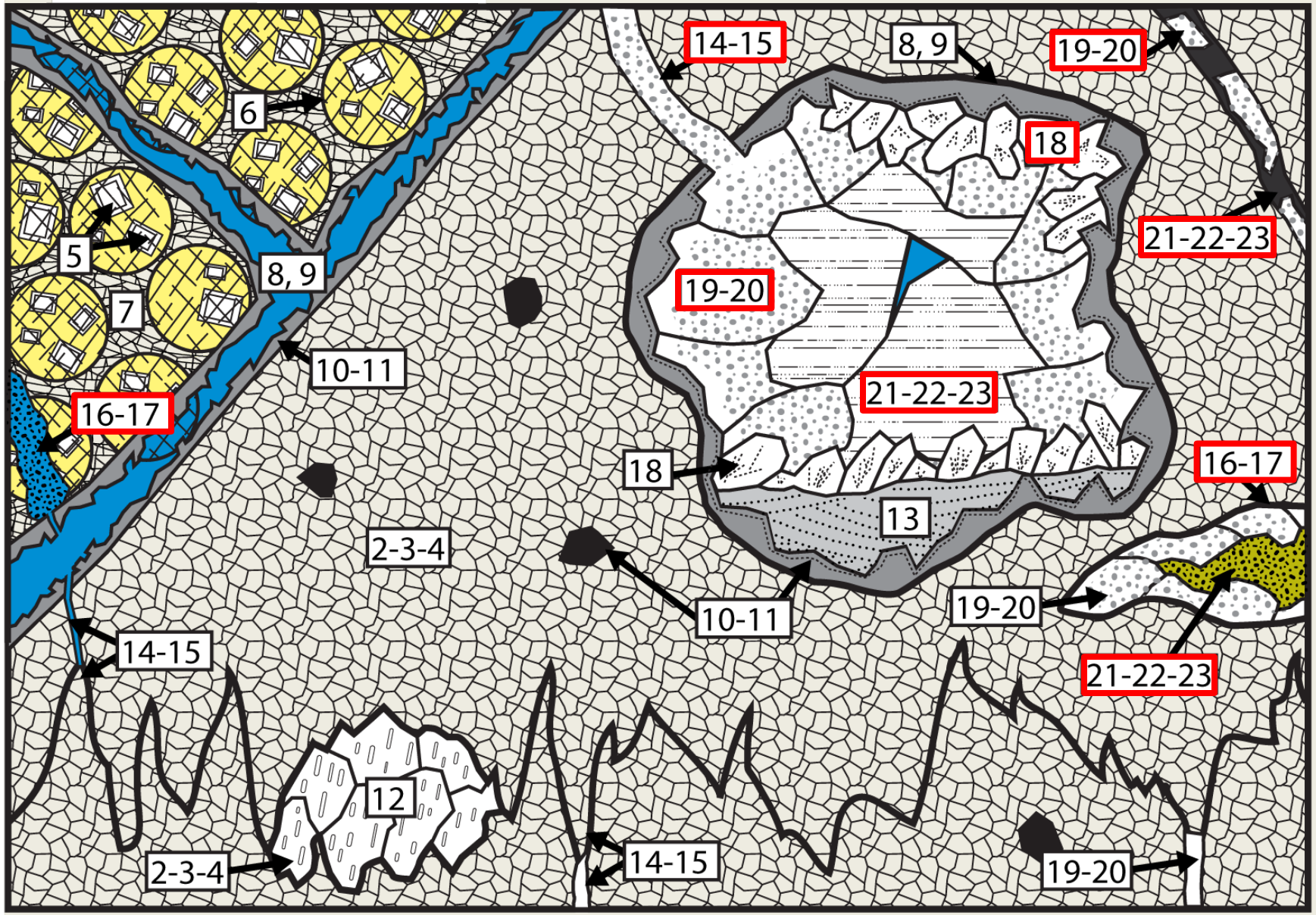

Nebraska
Rocky Mountains
Denver Basin
N
Missouri
Kansas
Central Kansas Uplift
Nemaha Anticline
Bourbon Arch
Tri-state MVT ores
Cherokee Basin
Ozark Uplift
Colorado
Oklahoma
Anadarko Basin
Arkansas
Arkoma Basin
Ouachita Mountains
Approximate Study Area
0
Kilometers
500
0
Miles
500

Kansas Geologic History

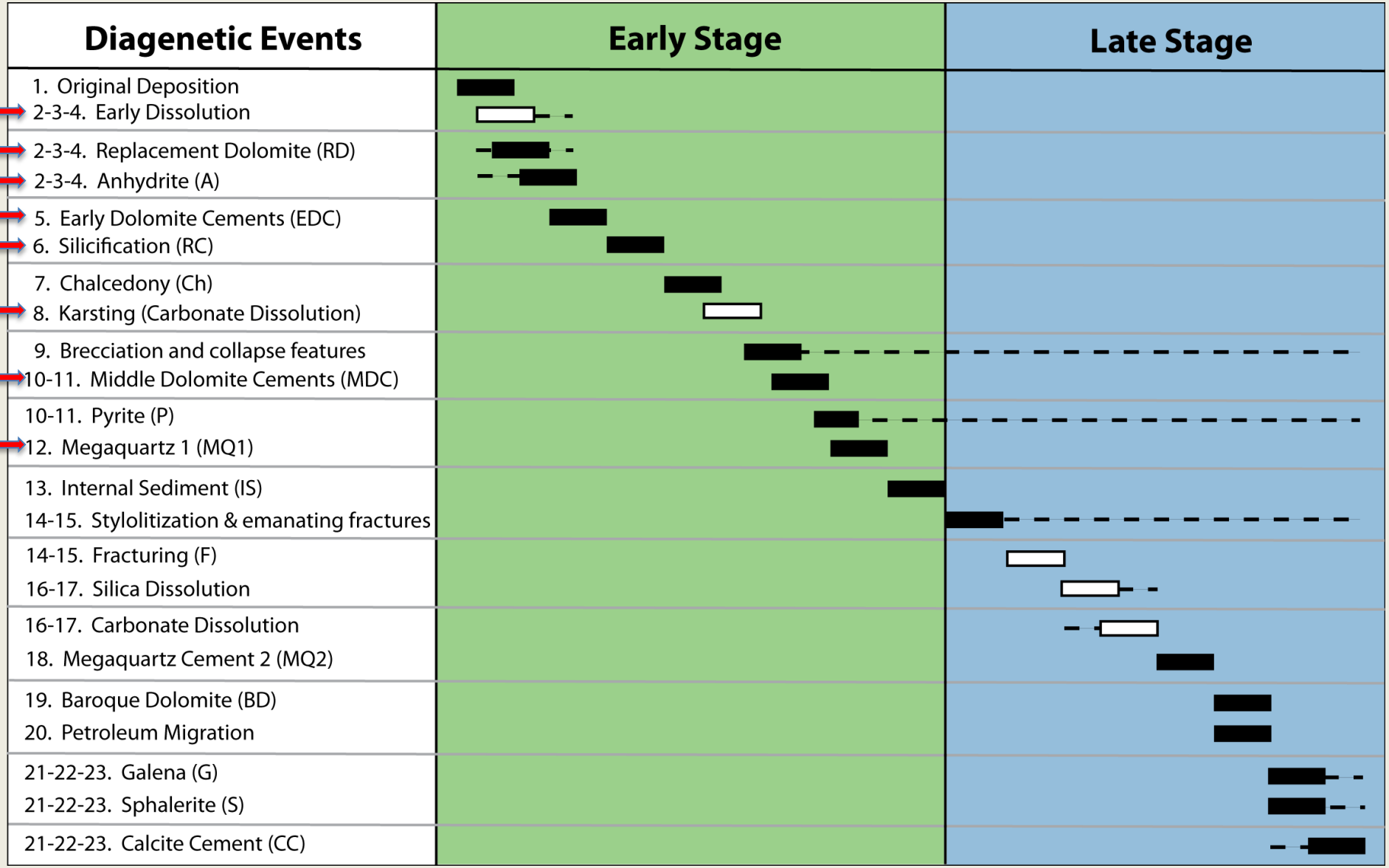


- Basal carbonates including unconformities and minor evaporites➔shale-rich section ➔evaporite-rich section
- Only moderate burial, conservatively no more than 60-70 °C burial heating
- Deep basins to the south originated as foreland basins in the Mississippian-Pennsylvanian
- Late Mississippian, Pennsylvanian, and Early Permian deformation associated with Ouachita-Marathon orogeny
- Late Cretaceous-Neogene structural reactivation associated with Laramide Orogeny

Arbuckle Group Ideal Paragenesis

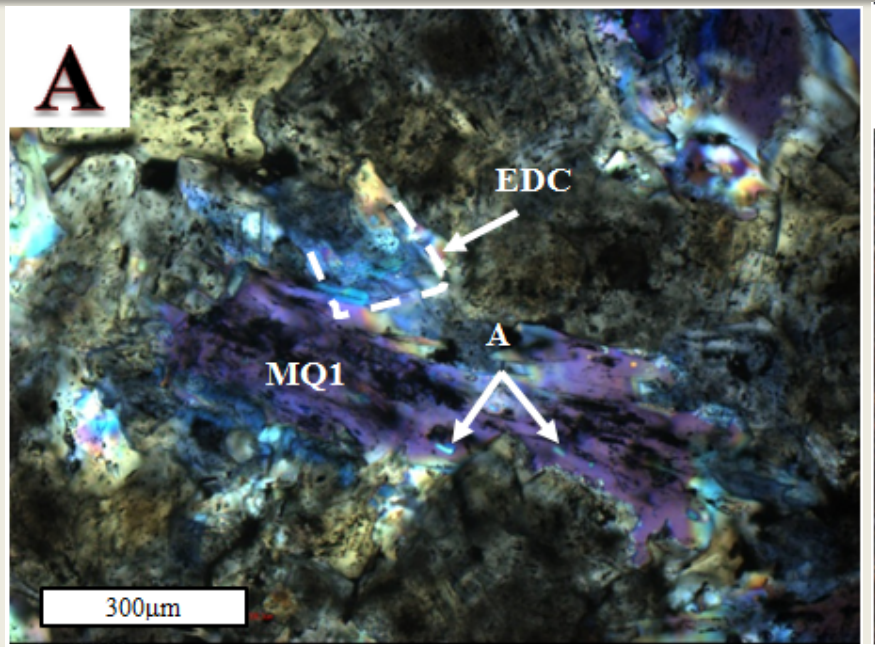


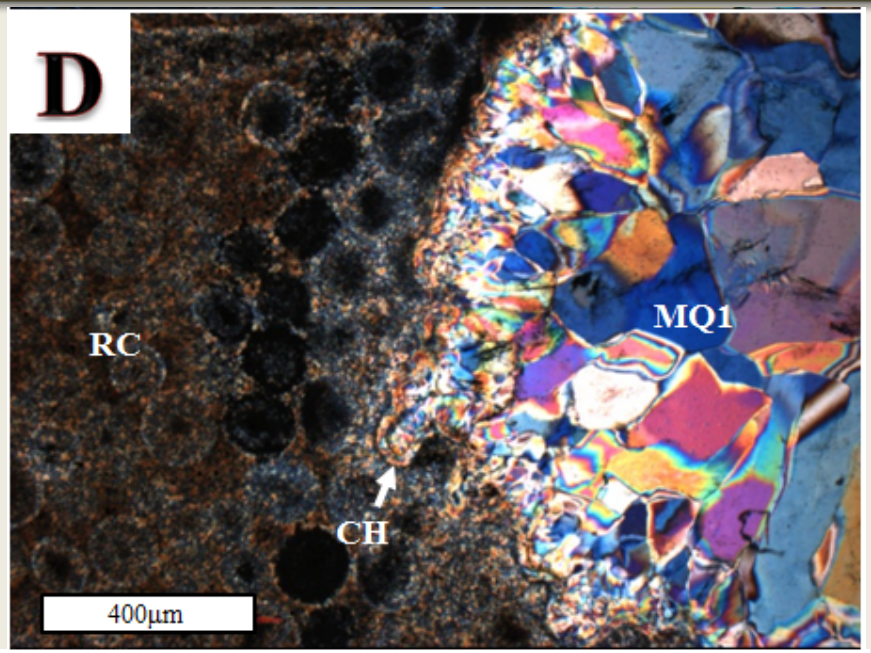
Arbuckle Group Paragenesis

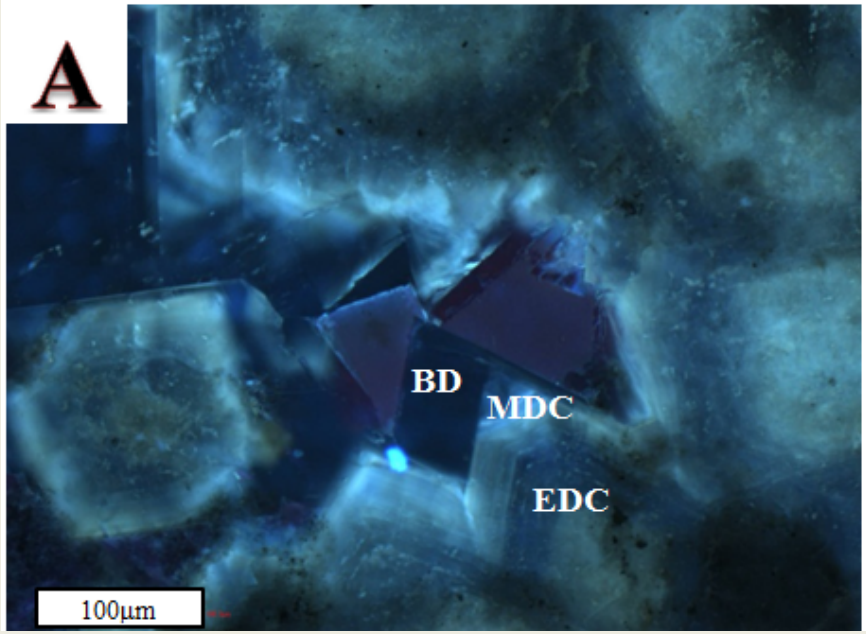


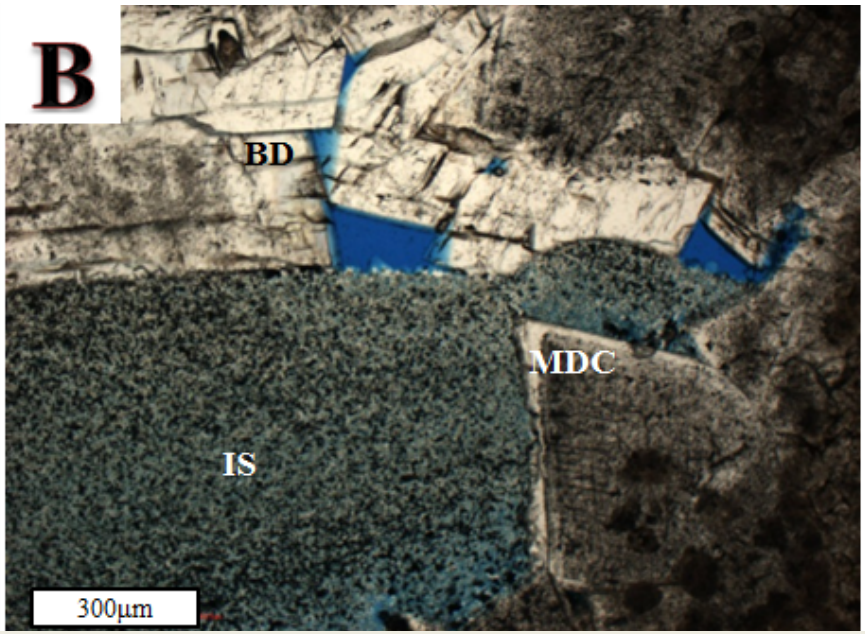
(After King and Goldstein)

Early Paragenesis



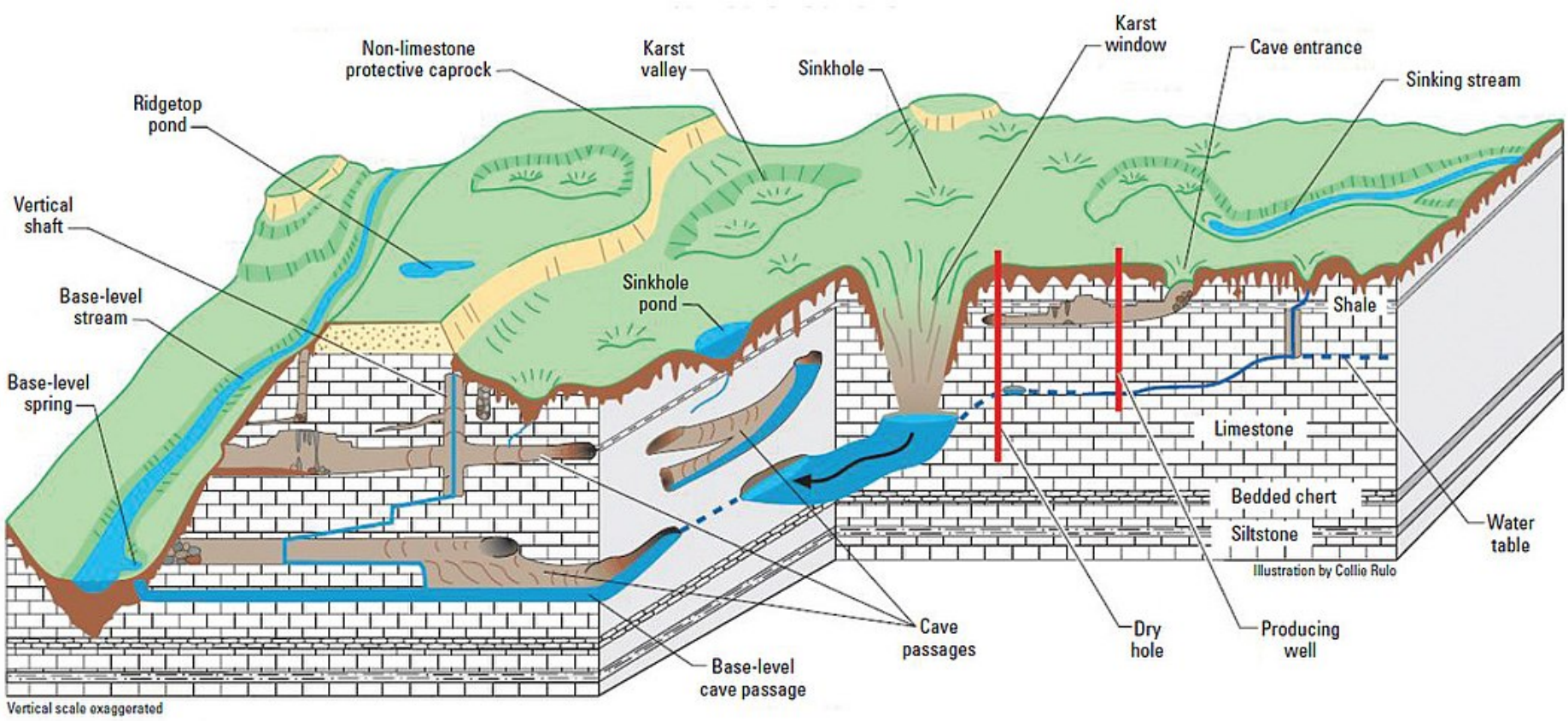






Early Paragenesis

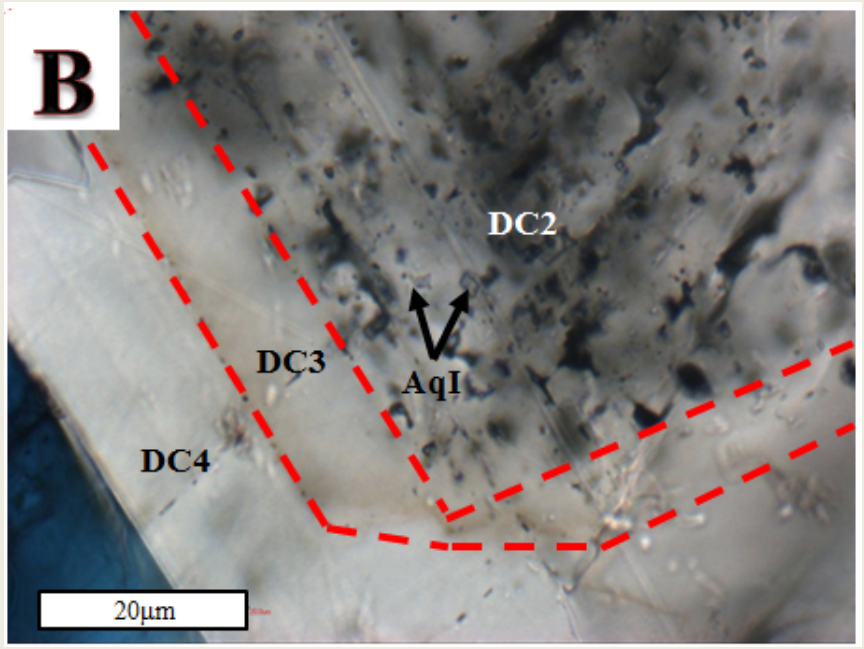
Karst dissolution caused by multiple events of Ordovician meteoric water infiltration

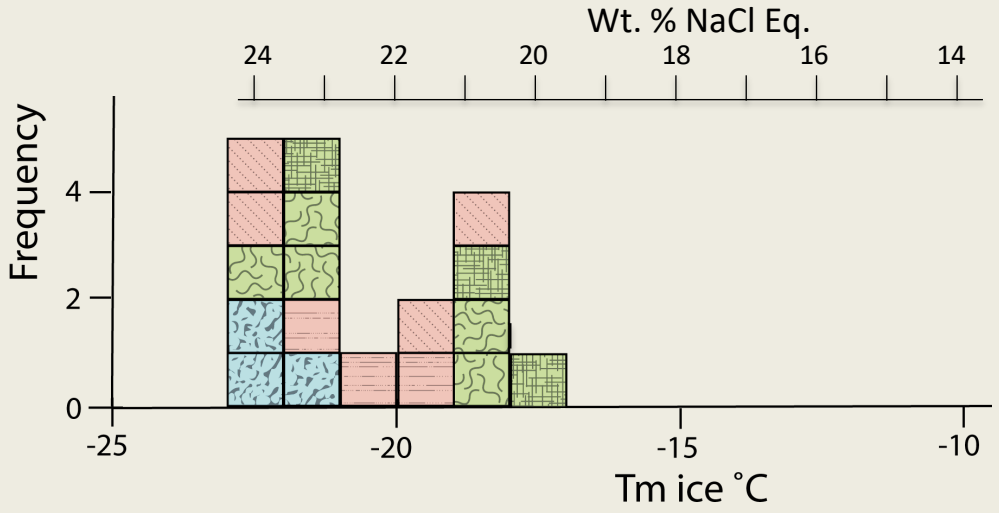


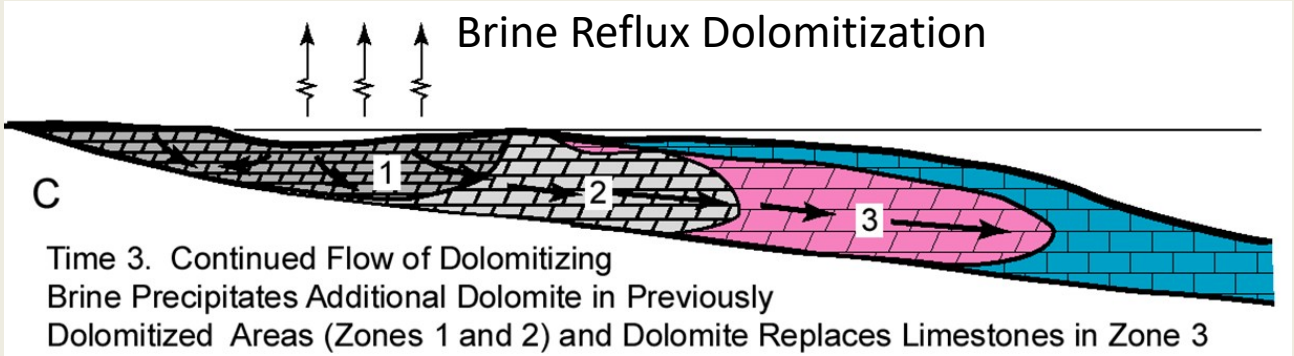
https://www.wikiwand.com/en/Karst

Early Paragenesis

Ordovician sinking of residual evaporite brines causes dolomitization

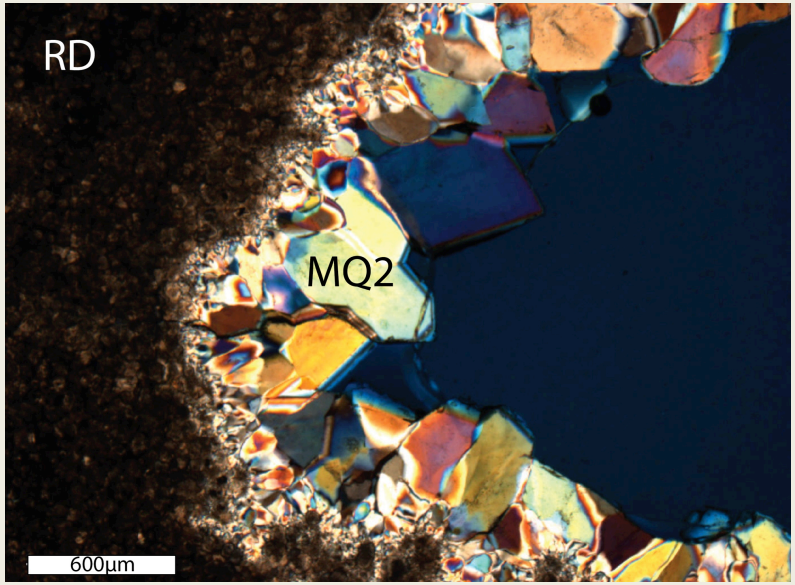


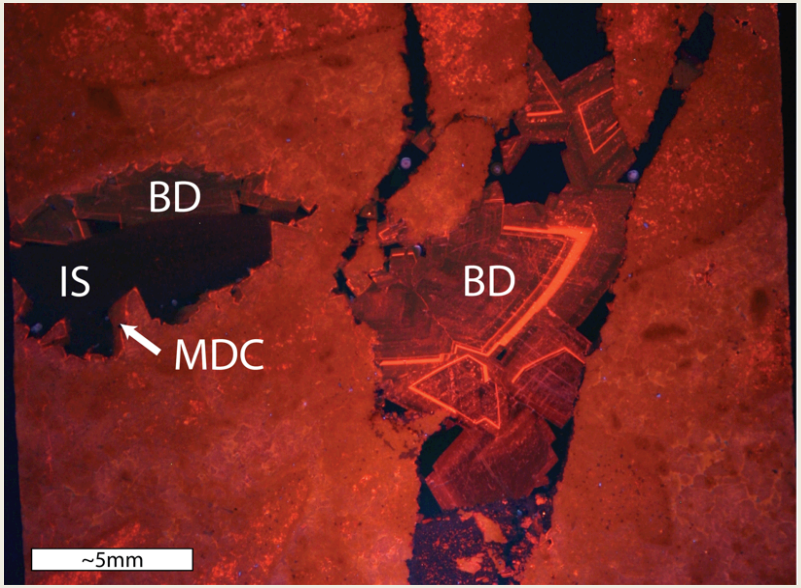


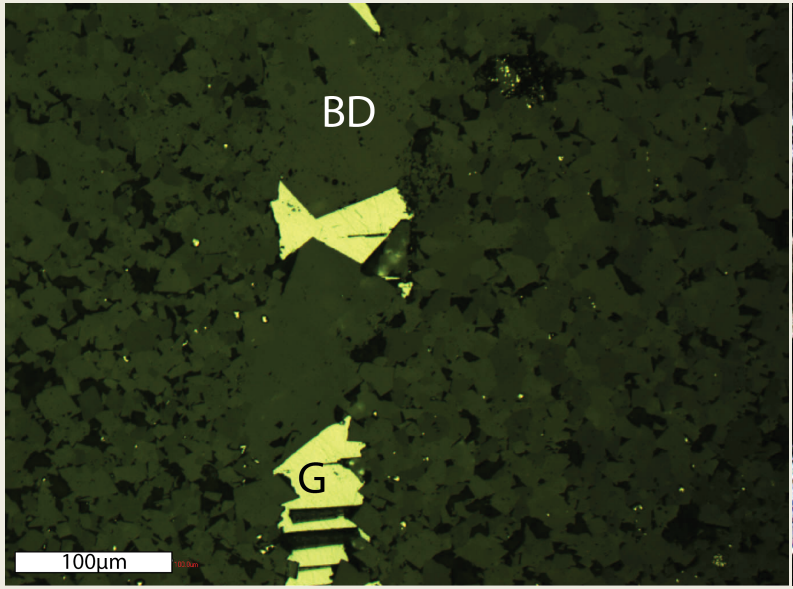


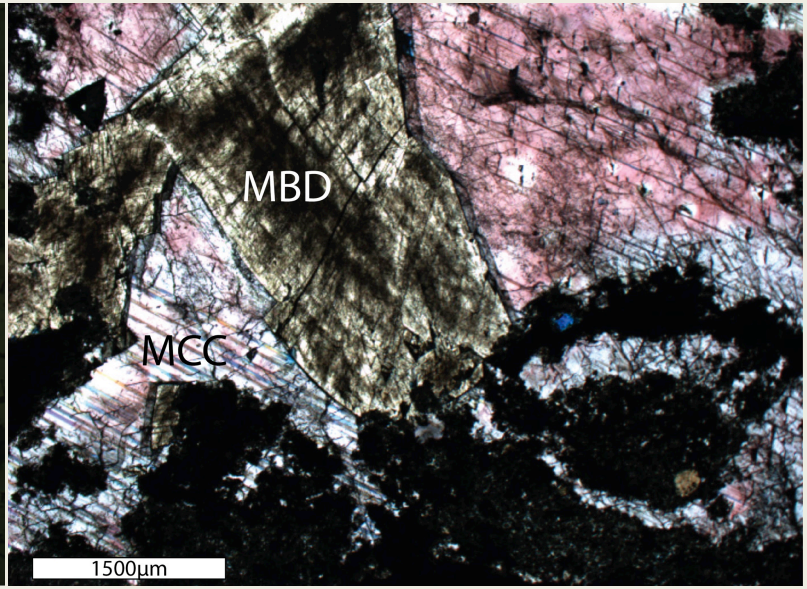
Saller, 2004

Late-Stage Paragenesis associated with fractures, after stylolitization and the same from Arbuckle up through Pennsylvanian Strata

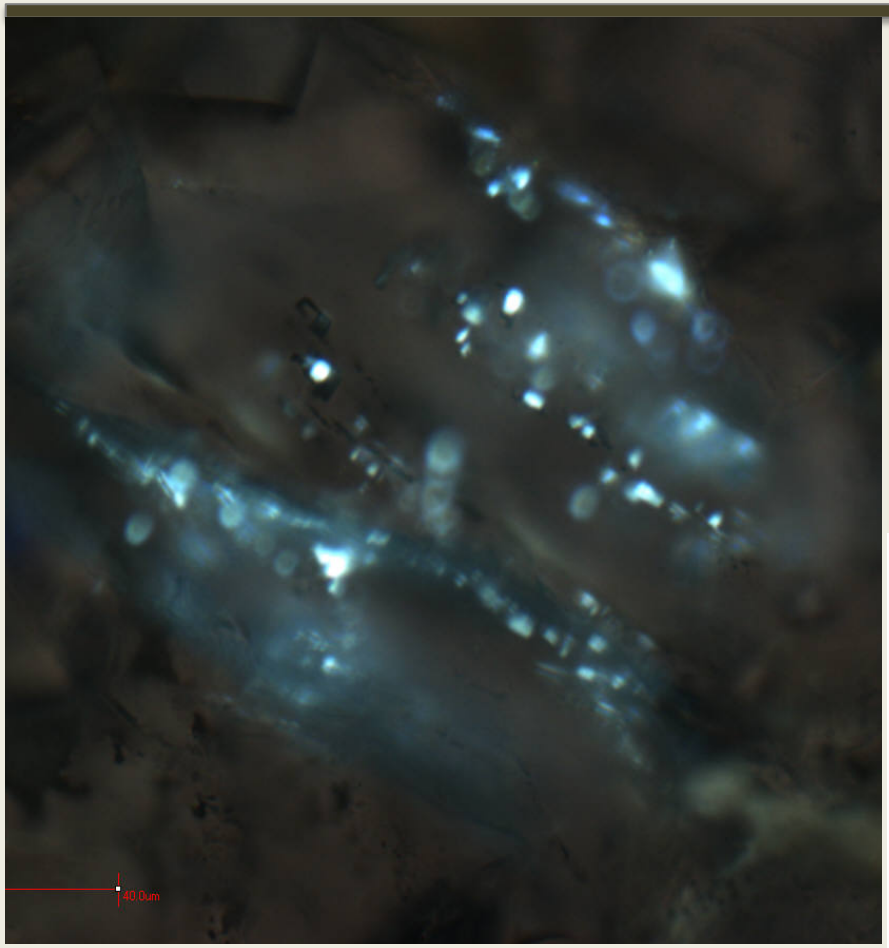




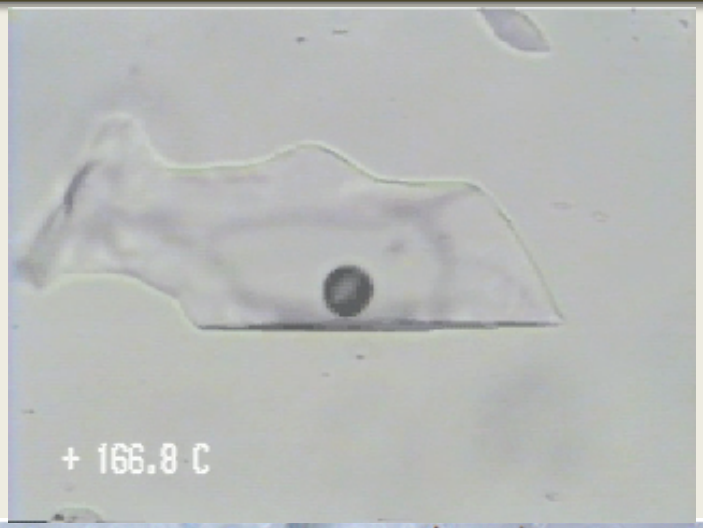


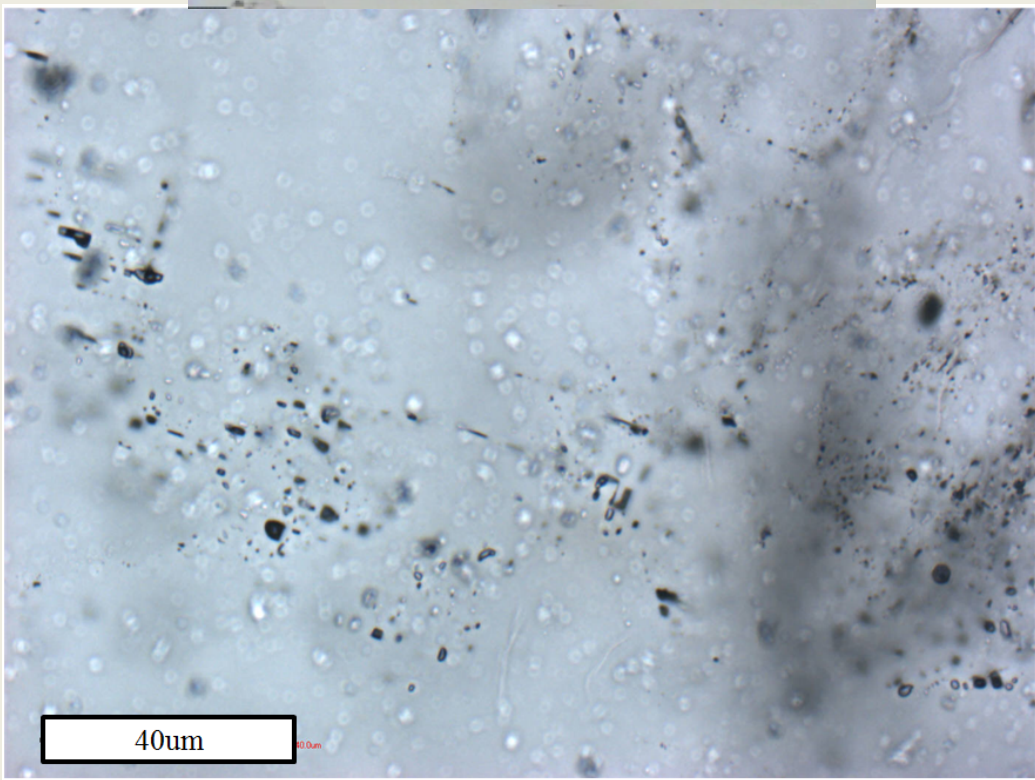


Late Mineral Phases – Hydrocarbons and Hot Brine



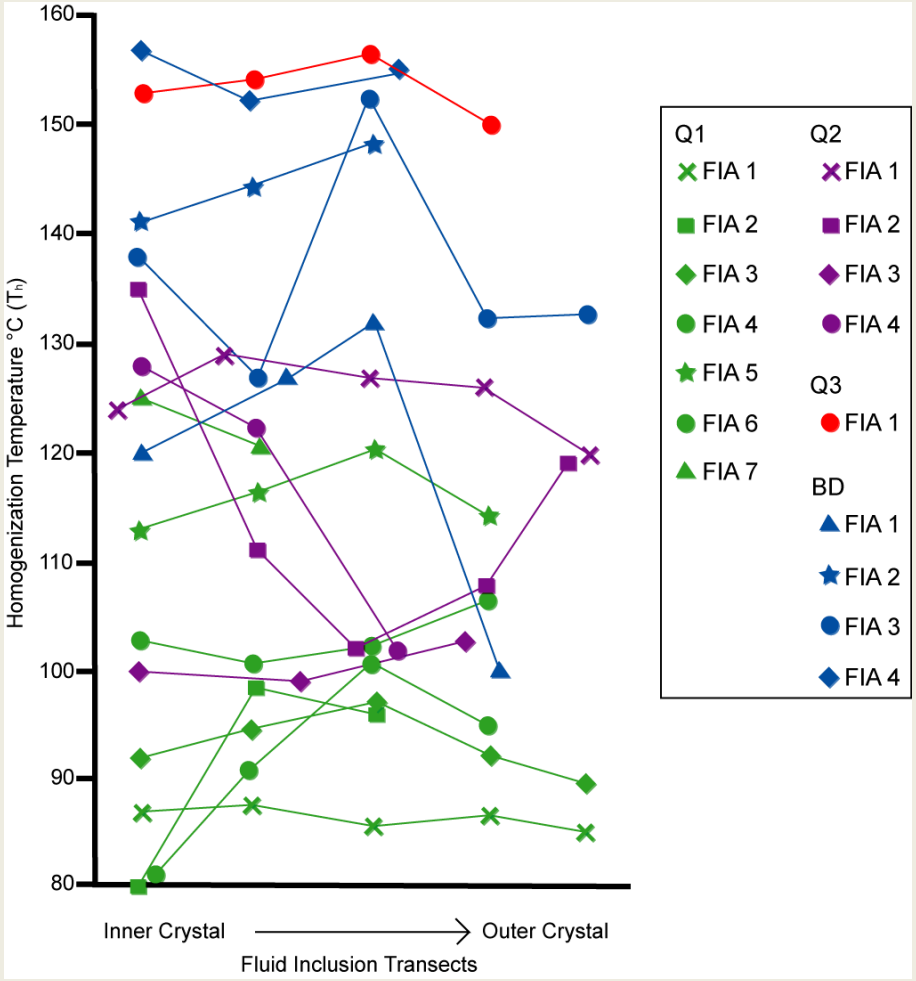
Oil during baroque dolomite

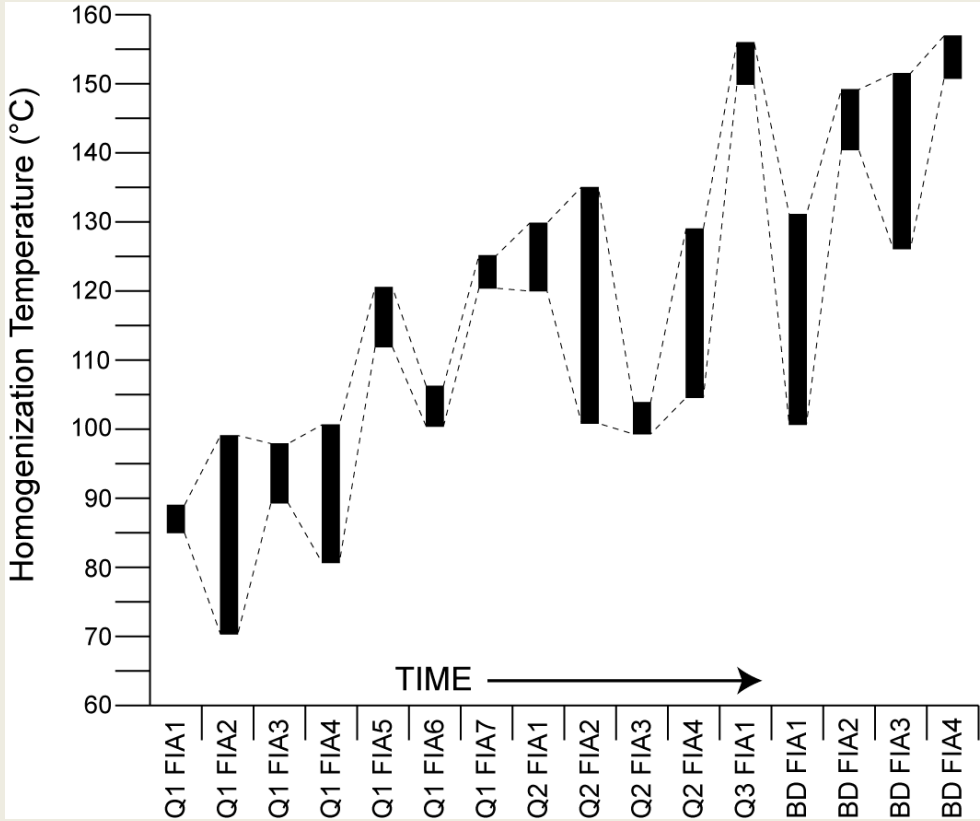




Gas during megaquartz➔

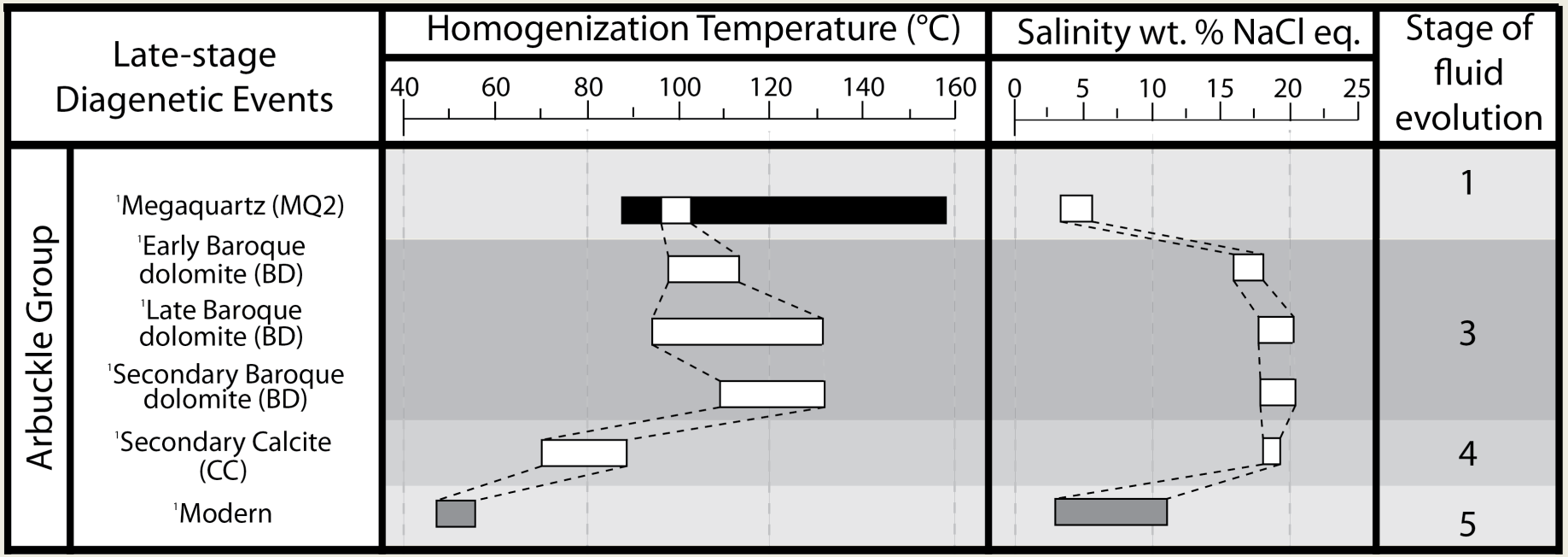
Fluid Inclusion Data – Hydrothermal



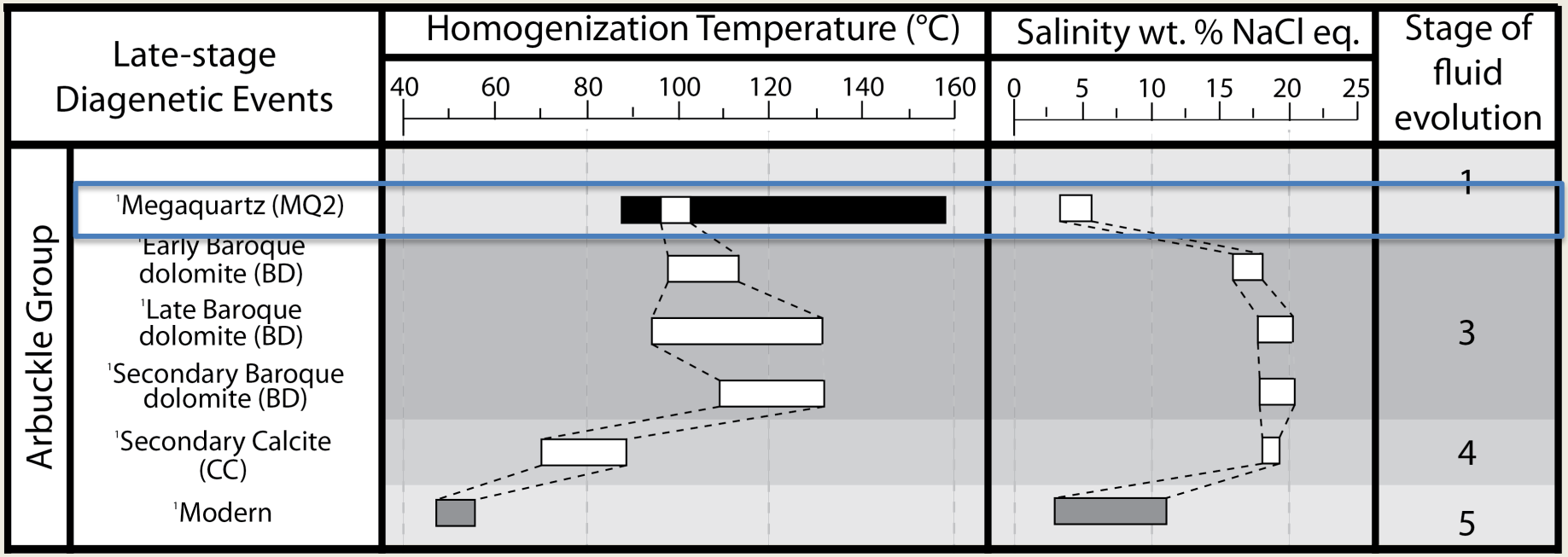


- Homogenization temperatures rise and fall through time - pulsed fluid flow

Five-Stage Record of Late Fluids



Stage 1 - Hydrothermal Flow



Stage 1 – Advective Flow of Connate Fluids

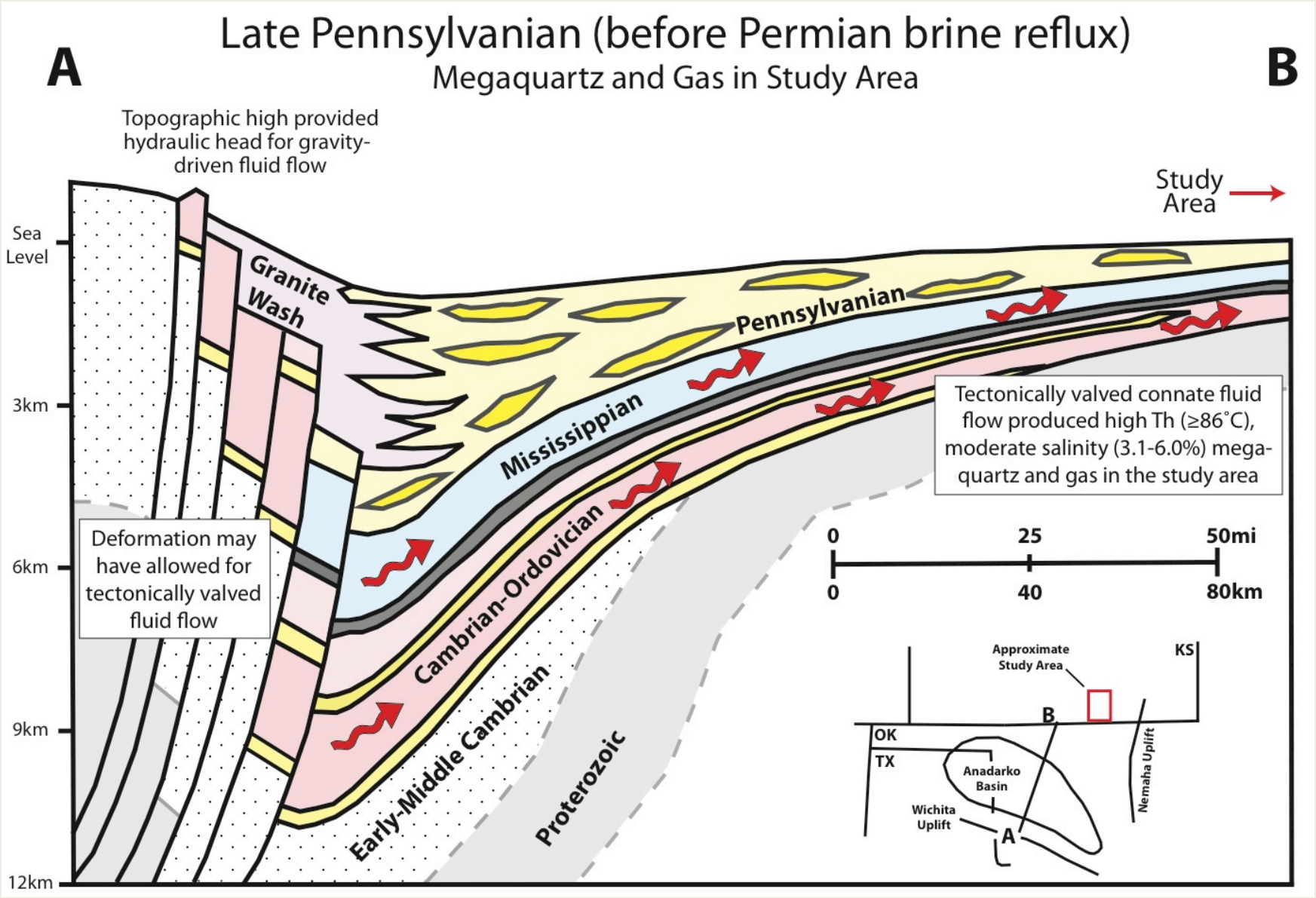
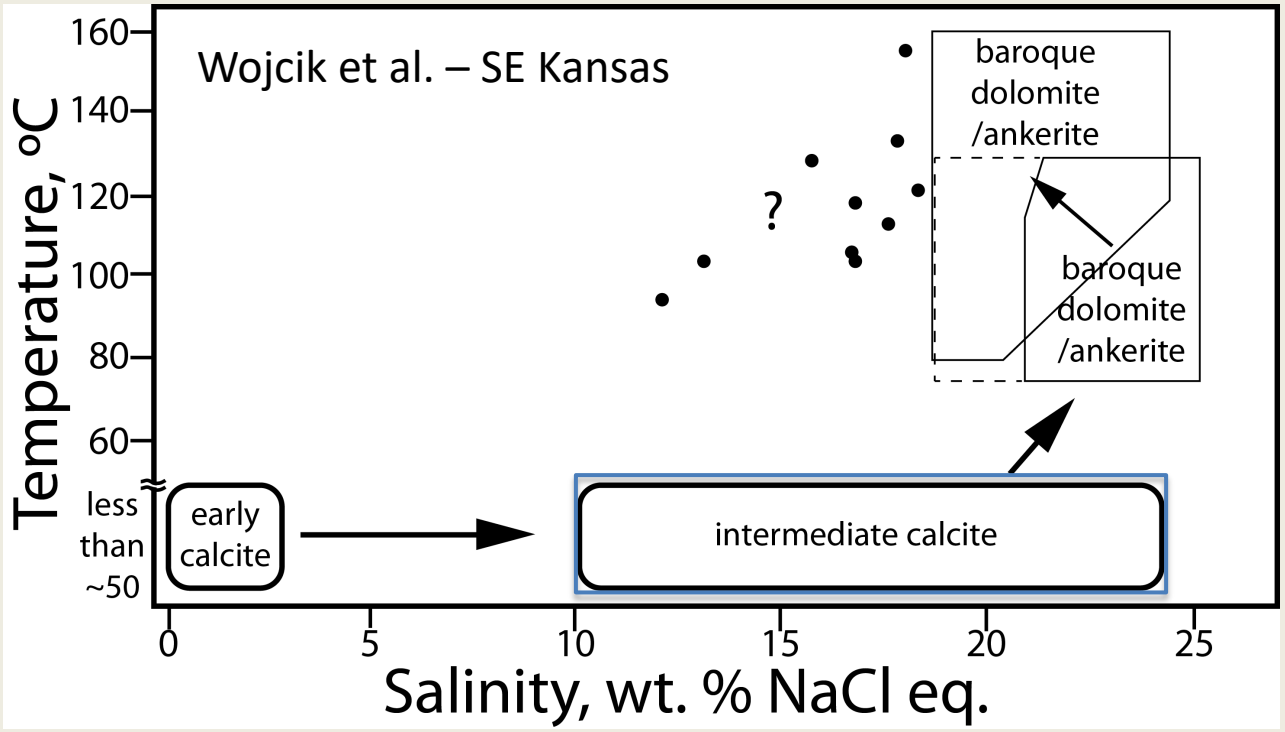
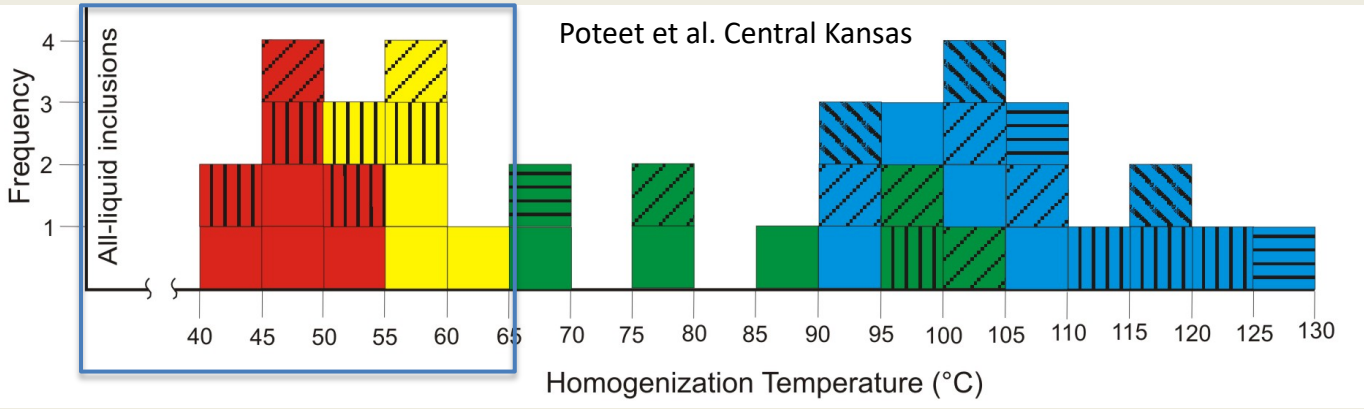


Image modified from Gallardo and Blackwell, 1999

Between Stages 1 and 2



- Mostly less than about 50°C
- Calculated fluid composition $\delta^{18}O$ of –1 to +4 ‰ VSMOW
- Origin must be related to brine reflux when Permian evaporites were being deposited



Between Stages 1 and 2 – Brine Reflux

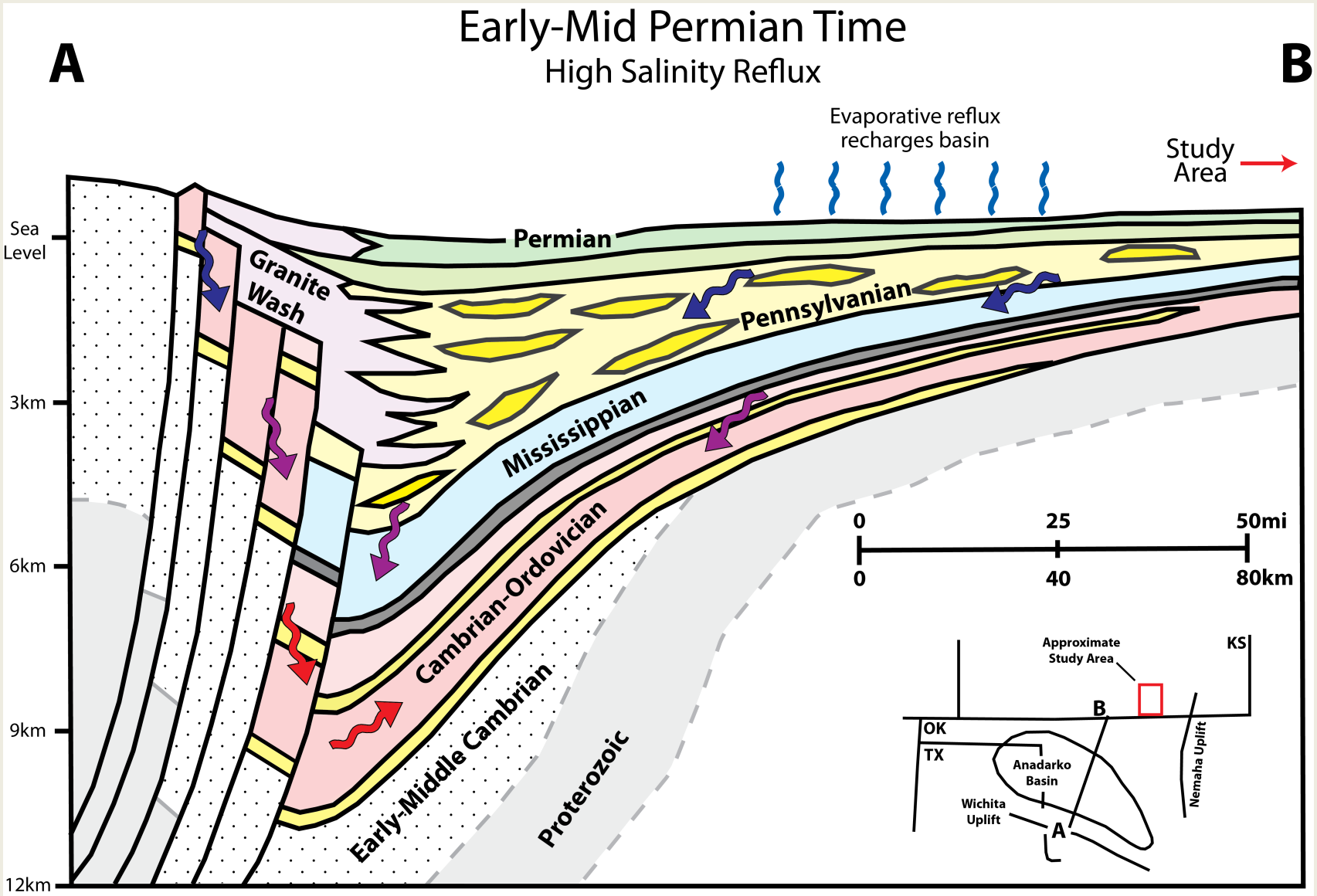
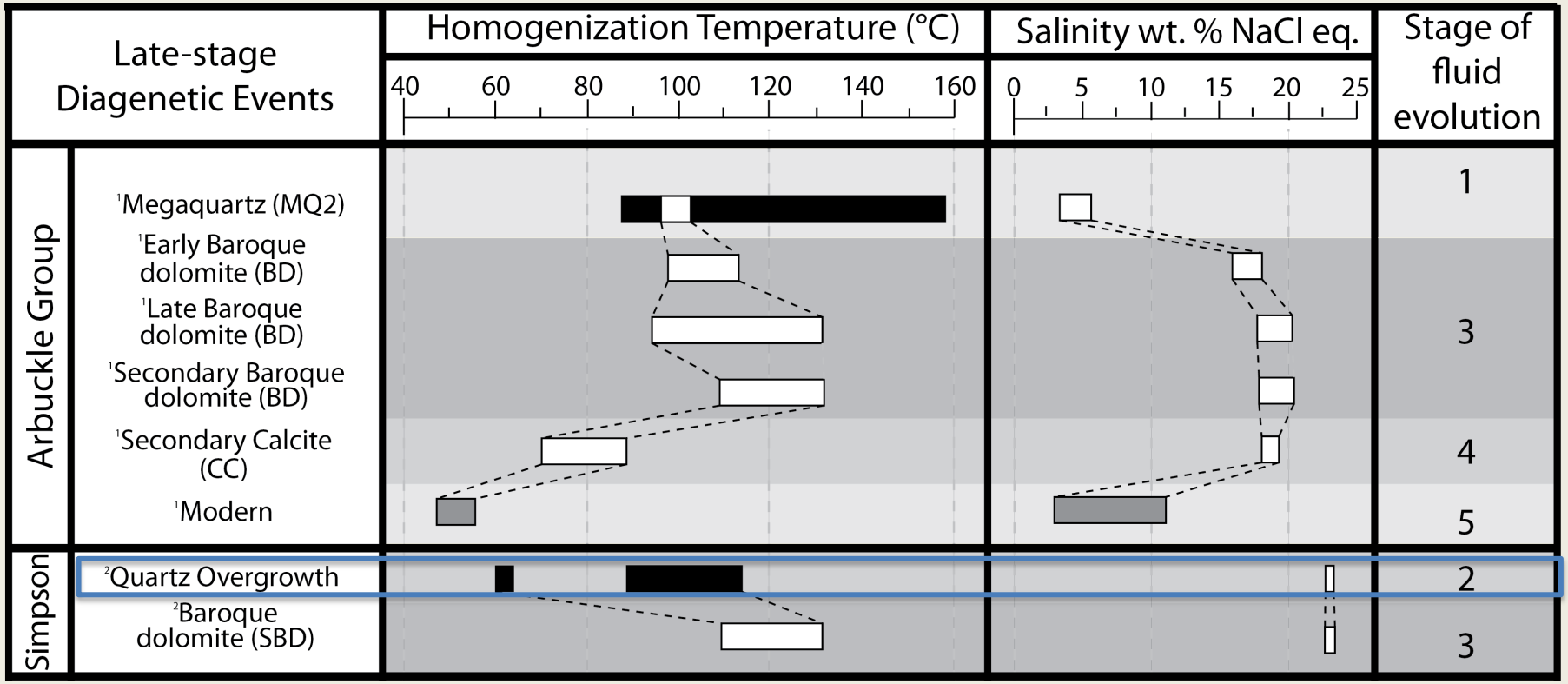


Image modified from Gallardo and Blackwell, 1999

Stage 2 - Hydrothermal Flow Mixing with Ambient Temperature Fluid



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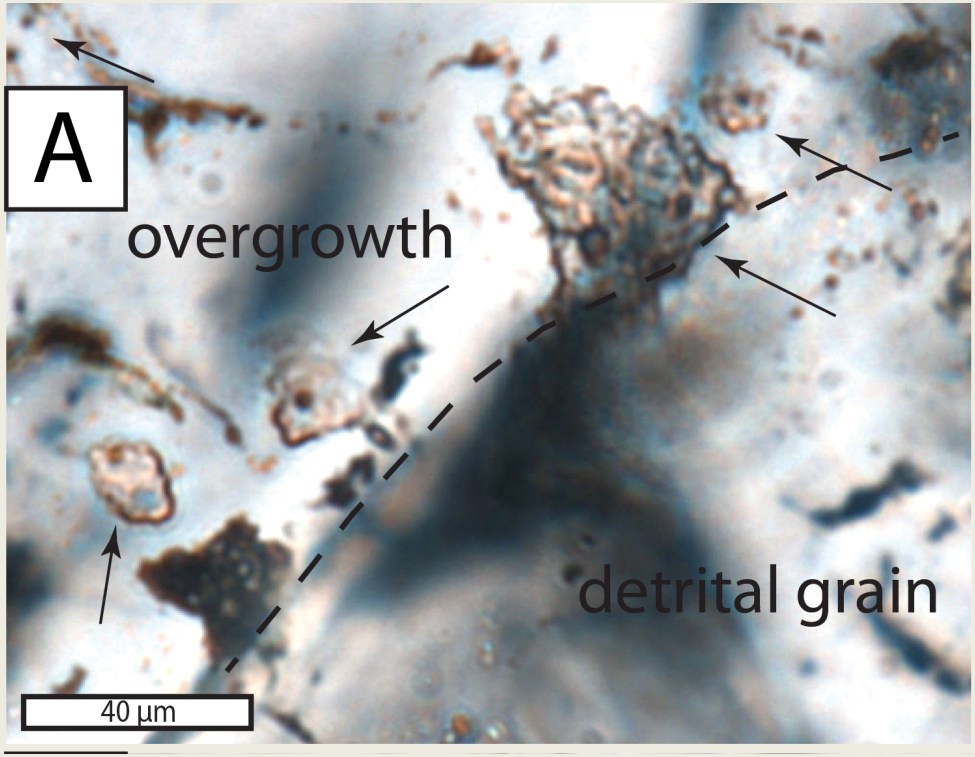
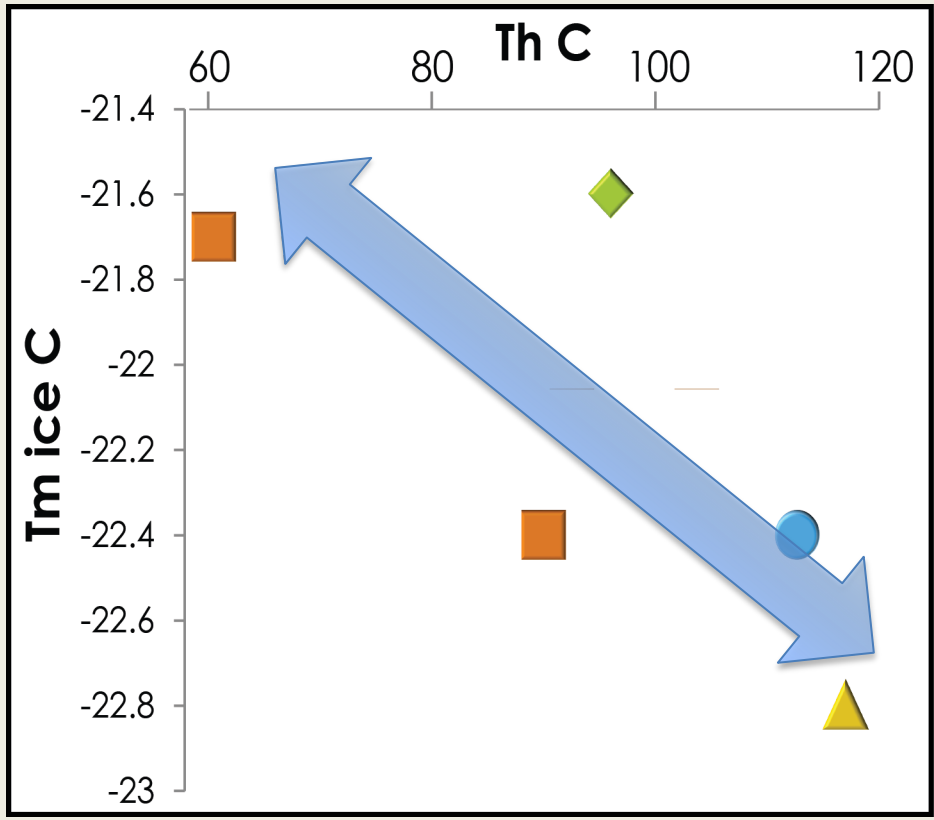
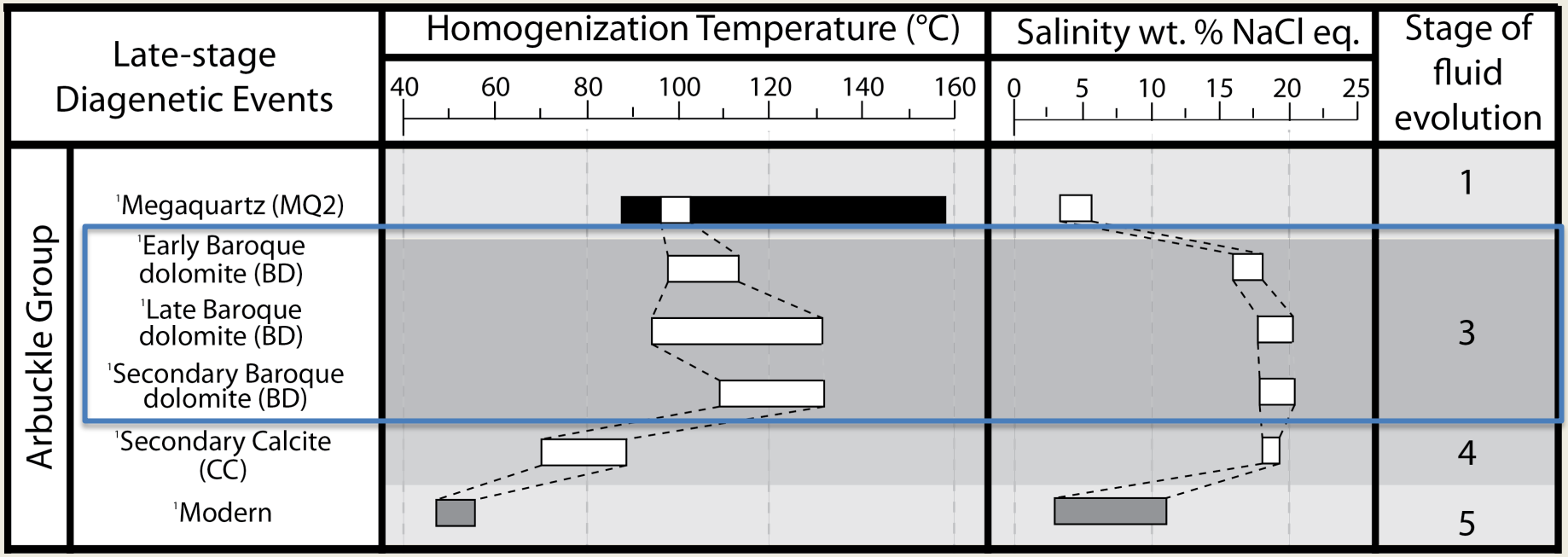


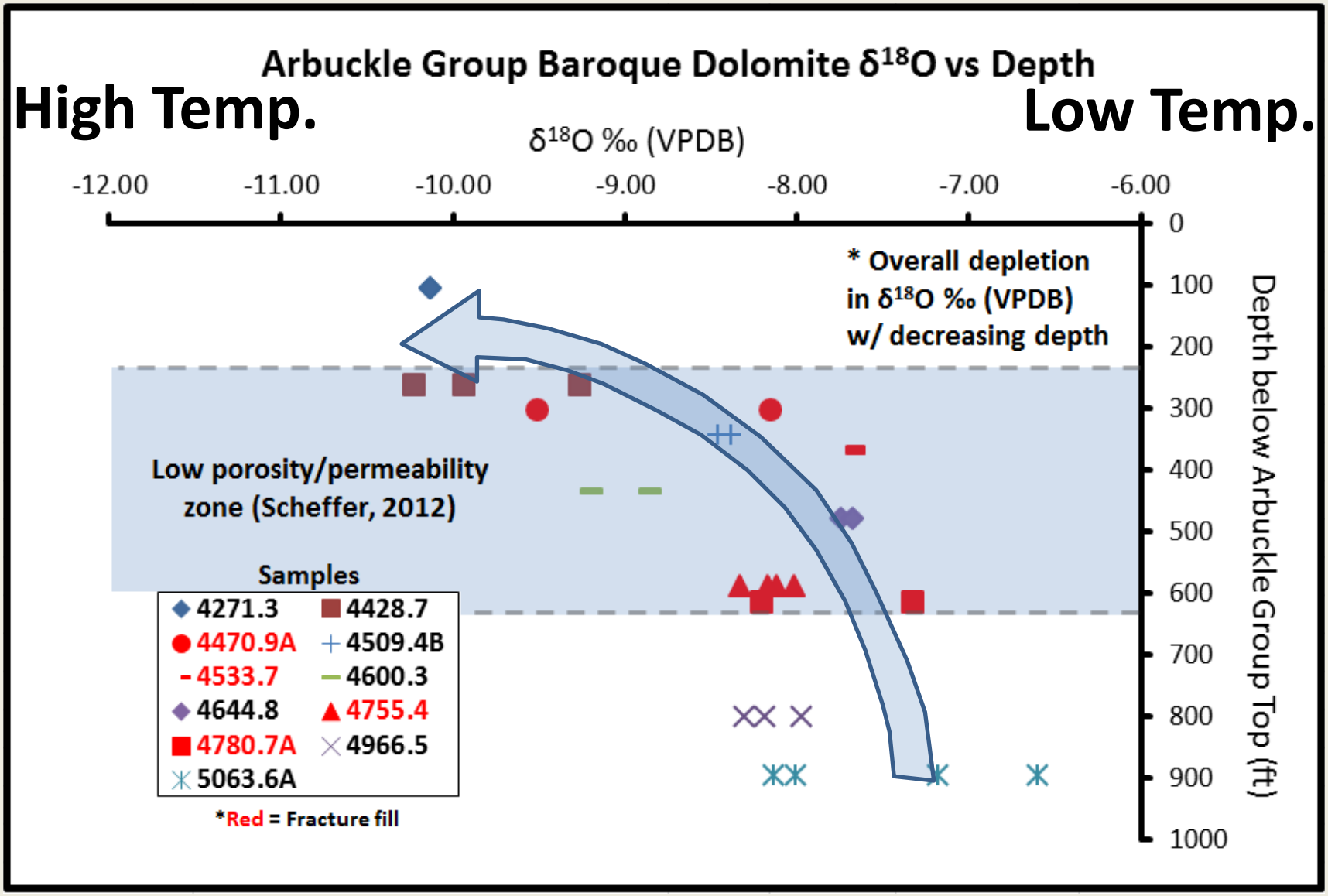


- Initiation of quartz overgrowth in Simpson Group Sandstone and continued qtz overgrowth in Mississippian
- Higher temperature in Mississippian than Ordovician but ranging from ambient burial to hydrothermal
- Correlation between high temperature and highest salinity

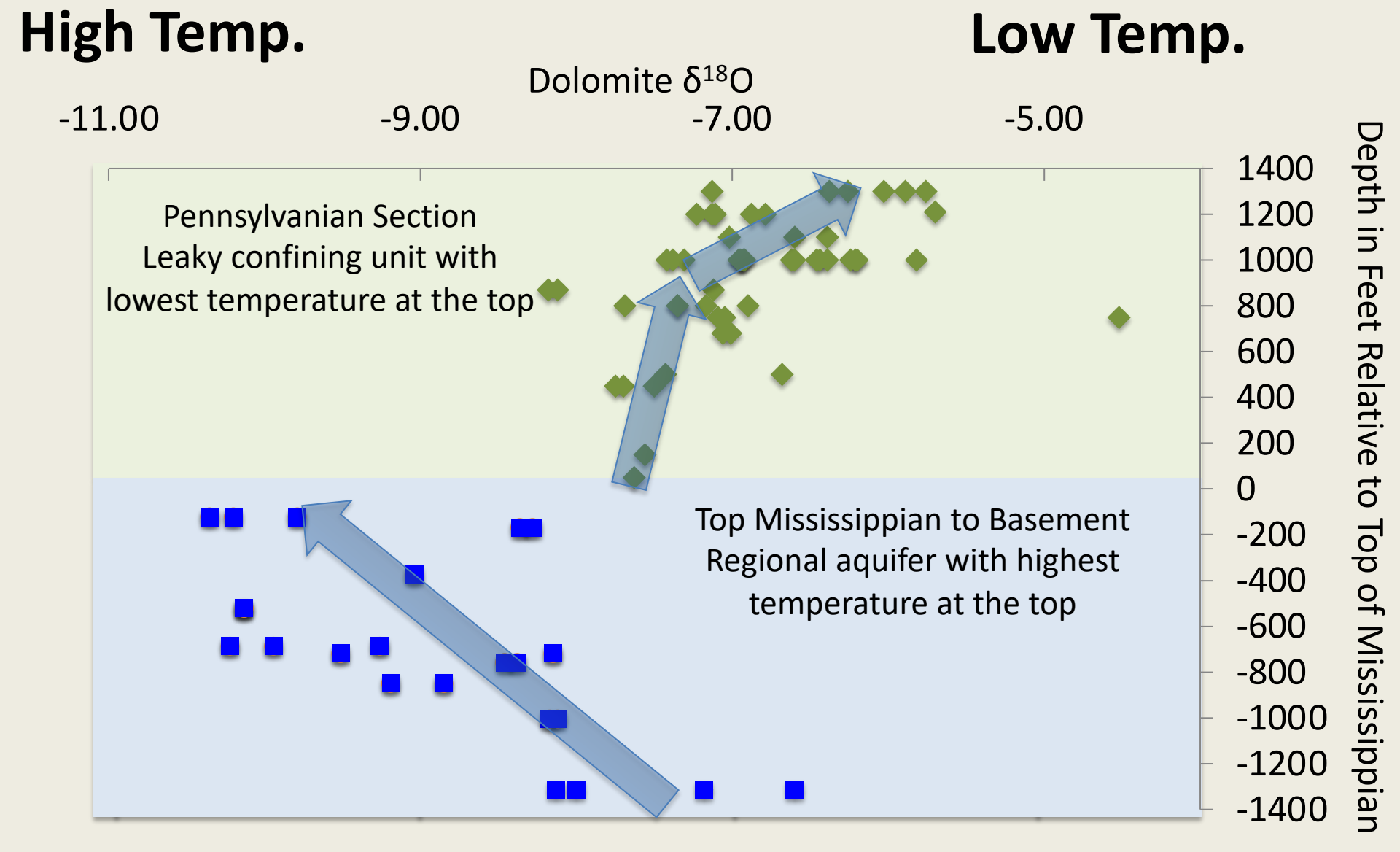
Stage 3 - Hydrothermal Flow



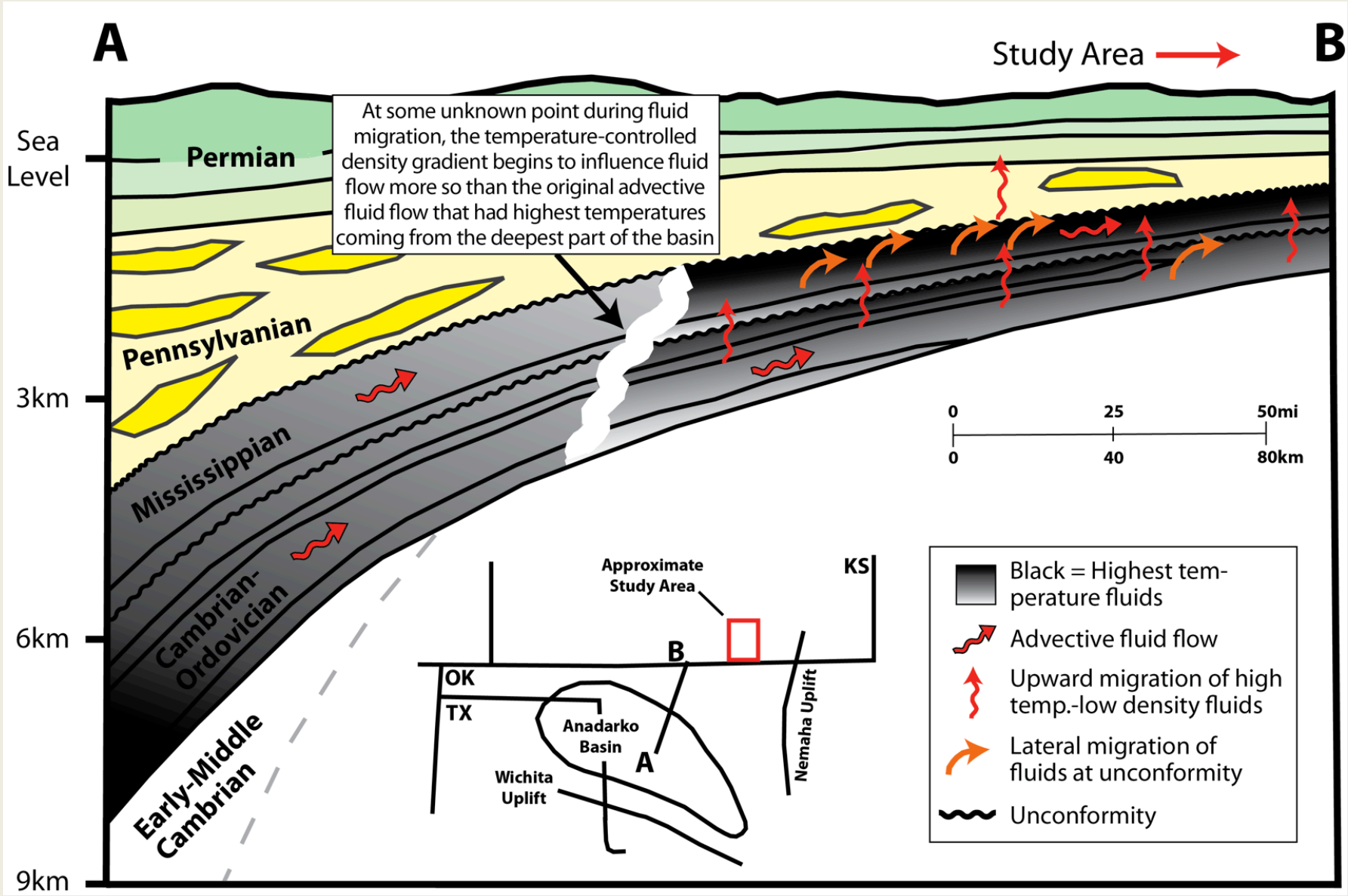
Stage 3 - Thermal Structure - Stage 3 Regional Fluid Flow



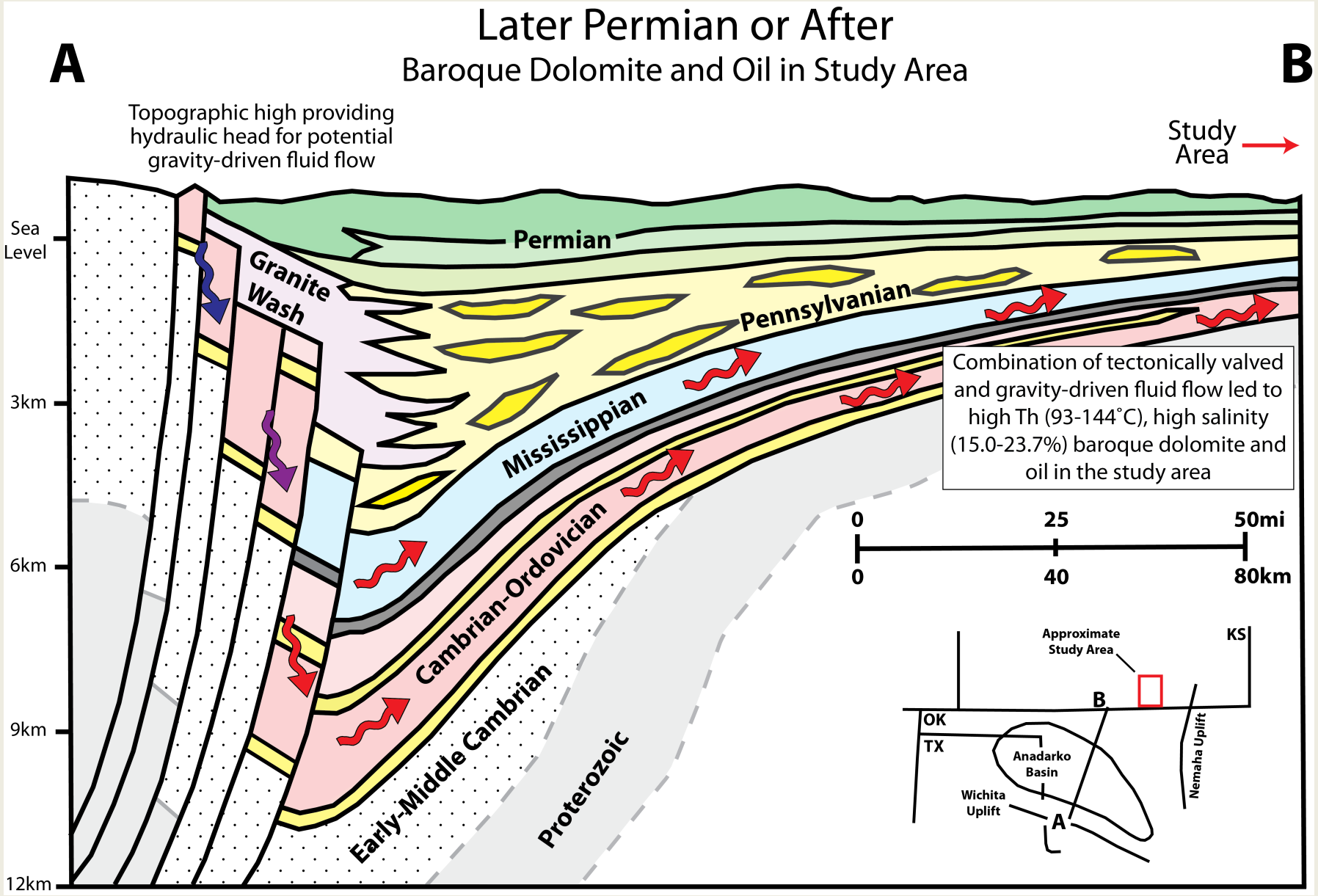
Stage 3 - Thermal Structure - Stage 3 Regional Fluid Flow



Stages 1-3 – Warmer fluids at top of Aquifer and Leakage into Confining Unit



Advective Fluid Flow – Stage 3



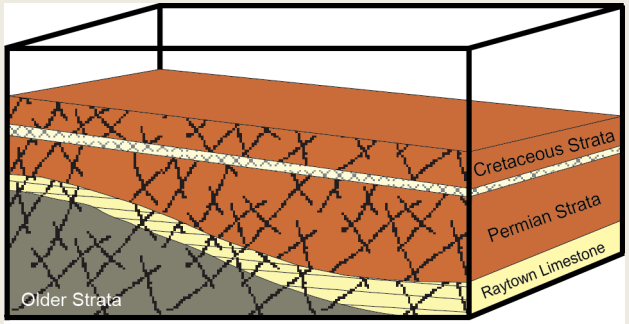
Stage 4 – Preceded by Fracturing and Dissolution

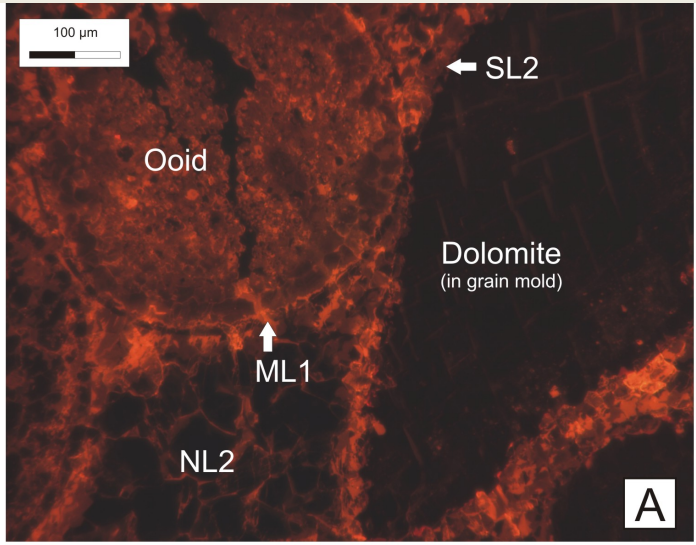
A Stratigraphic Unit	Diagenetic Events	Late Stage
Middle Ordovician Simpson Group	1-2. Fracturing (SF1) 1-2. Dissolution	
	3. Megaquartz cement (SMQ) 4. Baroque dolomite (SBD)	
	5. Fracturing (SF2)	

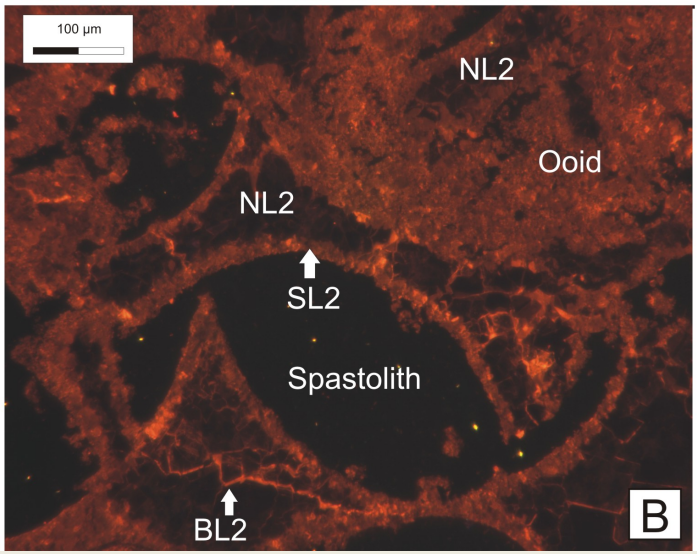
B Stratigraphic Unit	Diagenetic Events	Late Stage
Mississippian (Upper and Lower Series)	1. Dissolution 2. Brecciation	
	3. Megaquartz cement (MMQ) 4-5-6-7. Chalcedony (MCh)	
	4-5-6-7. Baroque dolomite (MBD) 4-5-6-7. Petroleum migration	
	4-5-6-7. Fracturing (MF)	
	8-9. Calcite cement (MCC) 8-9. Anhydrite (MA)	

C Stratigraphic Unit	Diagenetic Events	Late Stage
Middle Pennsylvanian Cherokee Group	1. Dissolution 2-3. Baroque dolomite (PBD)	
	2-3. Petroleum Migration	
	4. Fracturing (PF)	
	5. Calcite cement (PCC)	

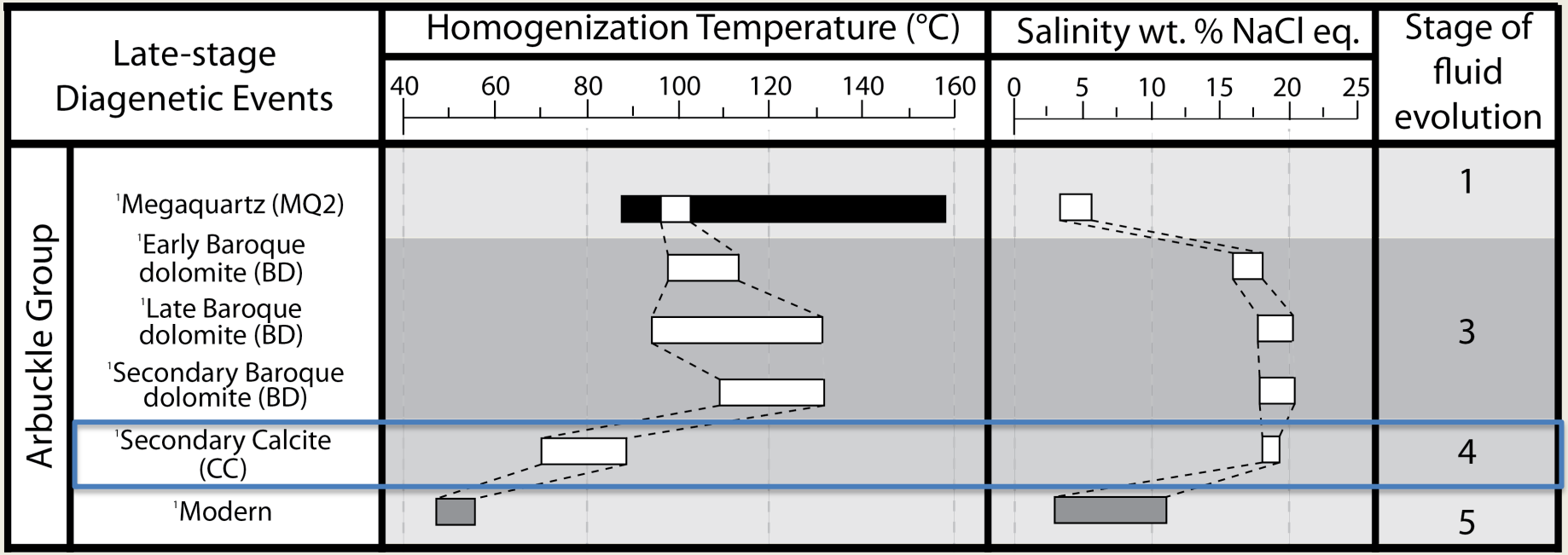
Fracturing opens up system and is followed by dissolution



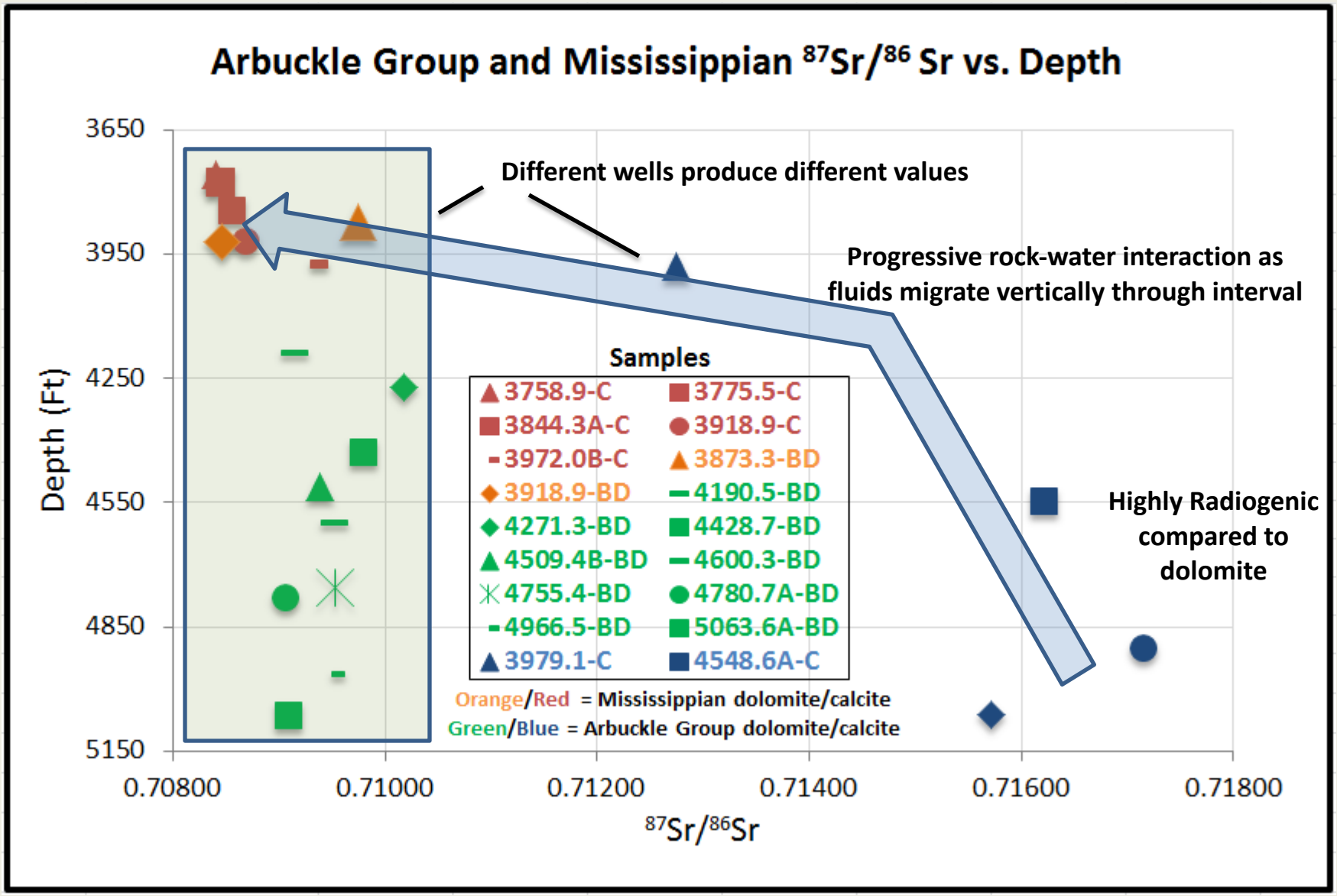




Stage 4 - Hydrothermal Flow



Stage 4 - Calcite $^{87}Sr/^{86}Sr$



Stage 4 - Fracture-Controlled Hydrothermal Fluid Flow and Calcite-Laramide?

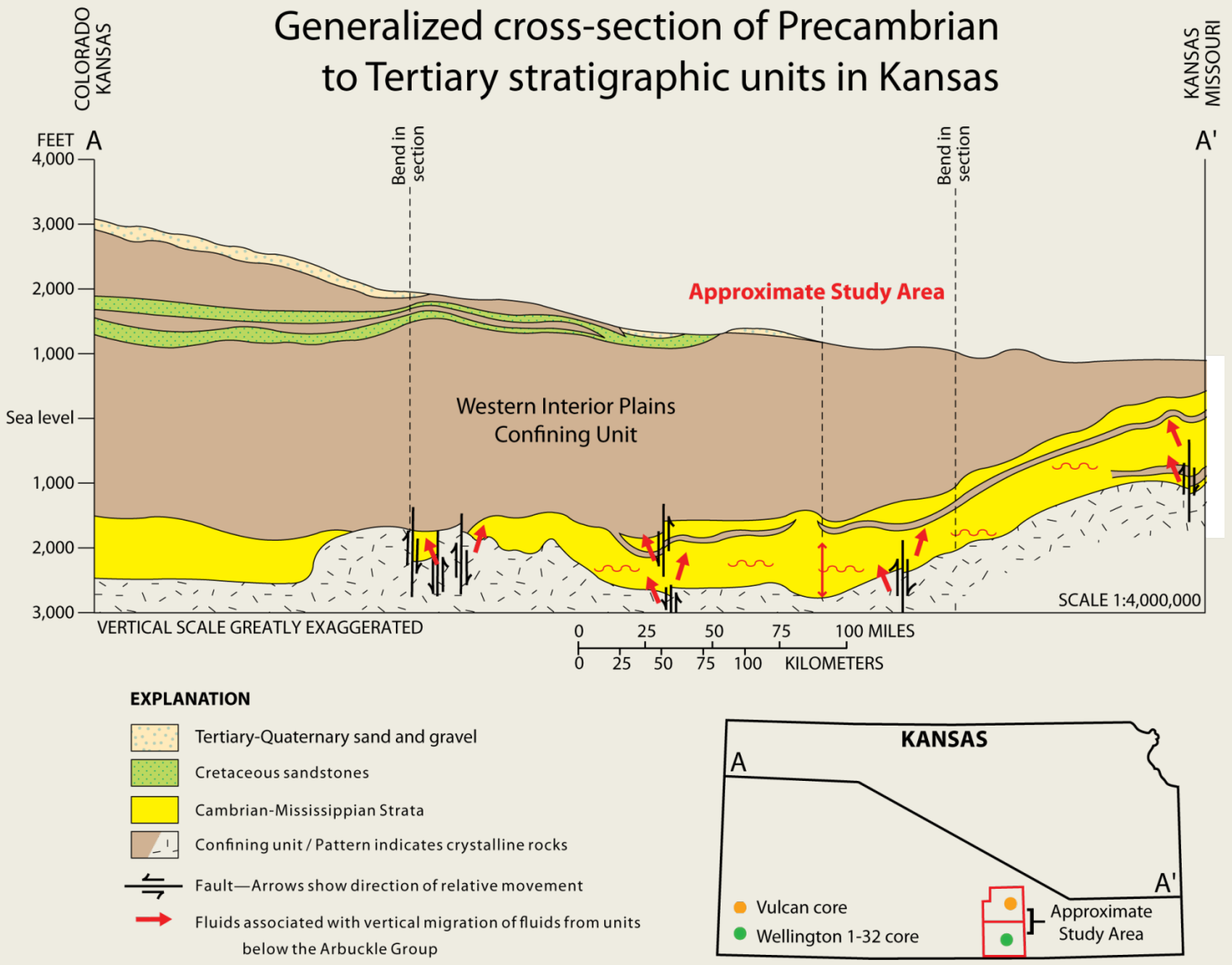
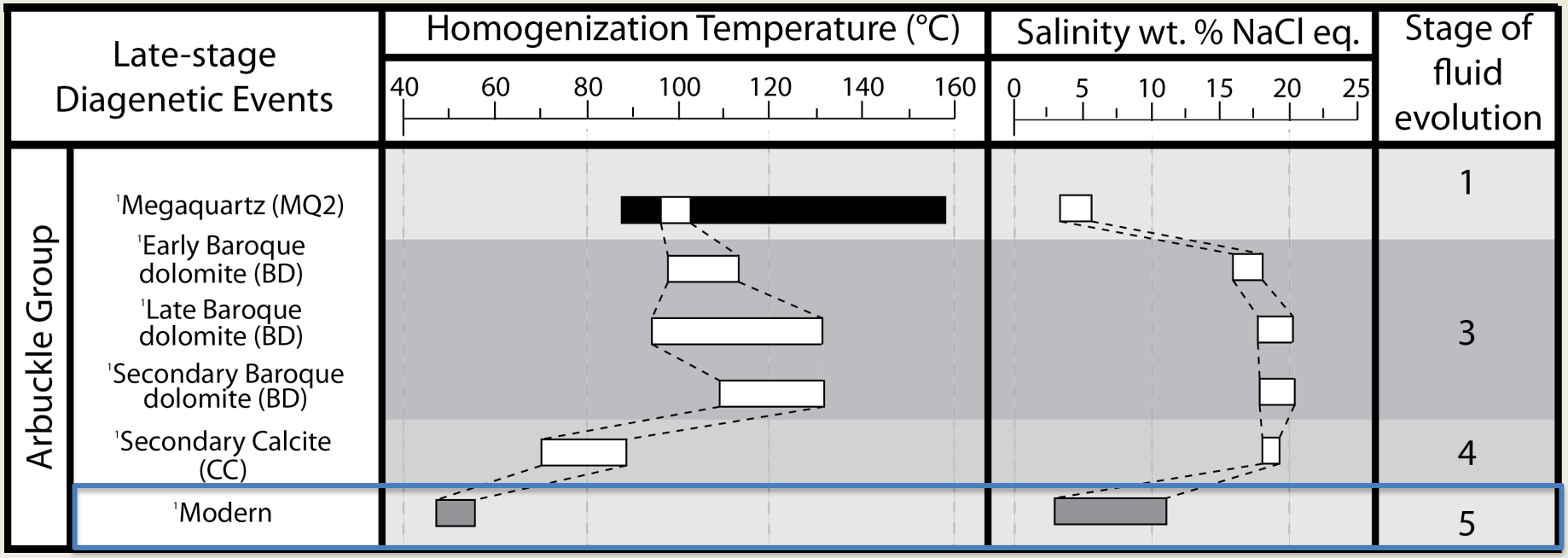


Image modified from Miller and Appel, 1997

Stage 5 – Extant Conditions



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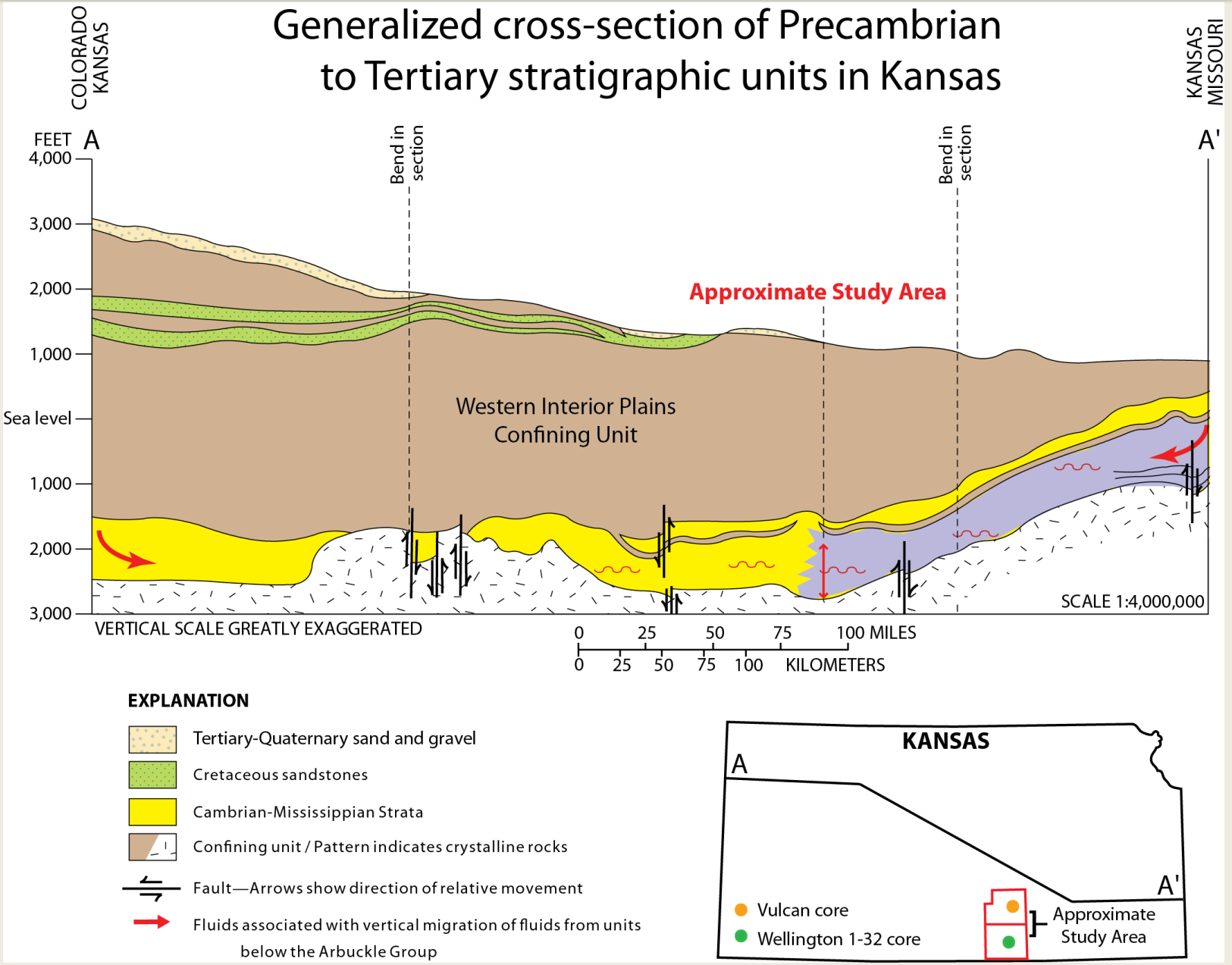

Conclusions

- Multiple events of low-temperature meteoric water infiltration in Ordovician
- Ordovician events of brine reflux and dolomitization
- Three stages of regional advective hydrothermal flow
  - Mississippian-to-Ordovician section acted as a regional aquifer and Pennsylvanian section acted as a leaky confining unit; lower density warmer fluids at the top of the aquifer
- A fourth stage of hydrothermal fluid flow, possible local fault pumping
- A modern fluid system with connection to the outcrop
- Implications are that under certain conditions, the Arbuckle Group has remained open to both lateral flow and cross-formational flow